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The Physico-Chemical and Bacteriological Characterization of Domestic Wastewater in Adétikopé (Togo, West Africa)

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Abstract: Wastewater represents a health risk for the population. For sanitary safety, it is important to know its physico-chemical and microbiological qualities in order to better understand the risks incurred by the population. The aim of this study was to analyze Adétikopé's domestic wastewater from a microbiological and physico-chemical standpoint. Twelve wastewater samples were taken in Adétikopé from December 2022 to February 2023. Physico-chemical parameters were determined in accordance with AFNOR and the French NF standard. In microbiology, AFNOR was used as a reference for the detection of germs contaminating wastewater. Results were assessed in relation to European Union Criteria 98/83/EC. The wastewater analyzed has a pH close to neutral, with an average pH of 7.05. The pollutant load generated ranged from 32 mG/L to 201 mg/L for BOD5, from 660 mG/L to 900 mG/L for COD and from 408 mG/L to 2080 mG/L for suspended solids. The highest levels of germs were detected in the samples taken, with values of 68,000 CFU/100 mL and 47,000 CFU/100 mL for thermotolerant coliforms and fecal streptococci, respectively. The results show that fecal contamination originates from both animal and human sources. Concentrations of fecal coliforms and fecal streptococci are very high, far exceeding WHO guidelines. While a short-term solution would be to disinfect household sanitation systems on a daily basis, in the long term, the construction of collective sanitation systems, backed up by environmental education, remains a sustainable solution for the health and safety of populations.

Keywords: wastewater; physico-chemistry; bacteriology; sanitary safety; Adétikopé

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1. Introduction

Water, which is present in large quantities on Earth and is essential to the survival of every living thing, animal or plant, is not just an ordinary liquid; it has original physical properties that result from the composition of its molecules and the way in which these molecules bind together. It can be found in three forms: liquid, solid or gaseous [1]. It must be classified as a universal heritage and therefore protected, defended and treated as such. It is a vital resource for mankind; it is also vital for our agricultural and economic activities, and the quality of our environment is closely dependent on it [2]. However, it is a universal receptacle for all types of pollution [3]. Although apparently inexhaustible, water is very unevenly distributed across the planet. In the short or long term, all countries will have to face up to the problem of water scarcity, as the mobilization of surface water has always been a major concern for public authorities [4].

This exacerbated use of water is due in part to the steady growth of the population, and changes in production and consumption patterns are leading to an ever-increasing production of wastewater of many different kinds, most of which is discharged directly into the environment, without any proper treatment. The various ways in which this waste is managed contribute to the discharge of potentially dangerous substances into the environment, raising many questions about their risk to human health [5,6]. Waste management is a major problem throughout the world. It poses both an environmental and a public health problem. These issues are becoming increasingly important in the various debates on sustainable development and are a major concern for both developed and developing countries. As a result, the environment is at the heart of a number of international meetings [7].

In Western countries, the question is posed in terms of the effectiveness of existing waste disposal methods, whereas in Africa, few countries are really interested in existing management methods [8]. Urban waste management is, therefore, one of the most worrying environmental issues for developing countries [9–11]. People's lack of knowledge or awareness of the issue, inadequate funding and institutional frameworks, and a lack of infrastructure, equipment and reliable data all contribute to exacerbating the difficulties encountered in managing the urban ecosystem in general and urban waste in particular [12,13].

These difficulties relate to the availability of water and sanitation. Access to essential water supply and sanitation services is highly inadequate in Africa. In rural areas, around 65% of the population does not have access to sufficient water, and 73% do not have access to adequate sanitation services. In urban centres, 25% and 43%, respectively, do not have access to sufficient water and adequate sanitation. This is because since the Drinking Water and Sanitation Decade, progress in coverage has stagnated, and the number of people without adequate services today is higher than in 1990 [14–16]. These problems pose challenges to the management of the continent's water resources and to the resolution of conflicts of interest between water, sanitation, food security, economic development and environmental protection [14]. In this sense, the African Water Vision 2025 aims for an Africa where water resources are used and managed equitably and sustainably for poverty reduction, socio-economic development, regional cooperation and environmental protection [14].

Togo, a West African country with an estimated population of 7.6 million in 2020, also faces water and sanitation difficulties and challenges [6]. Indeed, when it comes to sanitation and hygiene, households do not use a healthy method of evacuation. More than six out of ten households (67.5%) discharge wastewater directly into the environment, including 25.1% into the street. In Lomé, the capital, 52.5% of households discharge wastewater into the street, compared with 53.0% in urban areas generally [8]. To counter this, the public authorities have a roadmap combining the adoption of laws, their enforcement and various actions through strategies [17–21]. At the same time, the local population is supporting the authorities' actions with commendable initiatives that are helping them to acquire skills in water management [22]. As a result, the signs are favorable for achieving the UN target of reducing the number of people without access to quality sanitation from 51% of the world's population to 25% by 2030 [22].

To achieve this goal, it is necessary to improve the production and dissemination of knowledge, facilitate access to knowledge and the exchange of best practices, produce new information relevant to water-related sustainable development goals, raise awareness among the various players, encourage their networking, promote partnerships between them and their actions in coordination with existing initiatives to achieve water-related goals and targets and strengthen communication initiatives at various levels for the implementation of water-related goals [23]. In view of the decentralization process currently underway in the country, it is essential to have data on the health risks incurred by populations at the level of each sub-national territory.

This is the background to the present study, which is intended to contribute to sustainable local governance by providing data on raw wastewater from Adétikopé, the chief town of commune 6 in the Agoè-Nyivé Prefecture of Togo's Greater Lomé Autonomous District. Indeed, Adétikopé, with its rapidly increasing population, is not spared from this scourge [24,25]. Population growth and the gradual urbanization of this locality have obviously been accompanied by the massive production of household wastewater, resulting in the uncontrolled dumping of wastewater in the streets and near dwellings. Added to this is open defecation, particularly around the main market, and the dumping of septic tank effluent on vacant lots, a situation that becomes crucial during the rainy season. To this end, we set ourselves the goal of analyzing Adétikopé's wastewater from microbiological and physico-chemical points of view.

2. Materials and Methods

2.1. Study Framework

Geographical Study

Adétikopé (Adéti-Kopé) is the administrative center of commune 6 in the Agoè-Nyivé Prefecture in the Greater Lomé Autonomous District in the Maritime Region of Togo, a country in West Africa with the region code Africa/Middle East TO18. The geographical coordinates are 6°19′23″ N and 1°12′57″ E in DMS (degrees, minutes, seconds) or 6.32306 and 1.21583 (in decimal degrees). The choice of Adétikopé is not accidental, given the degradation of the environment in this district, which is having a negative impact on the health situation. Added to this is the fact that Adétikopé reflects the image of a continuous peri-urban commune of the city of Lomé in the midst of an urbanization revolution (PEUL project) (Figure 1).

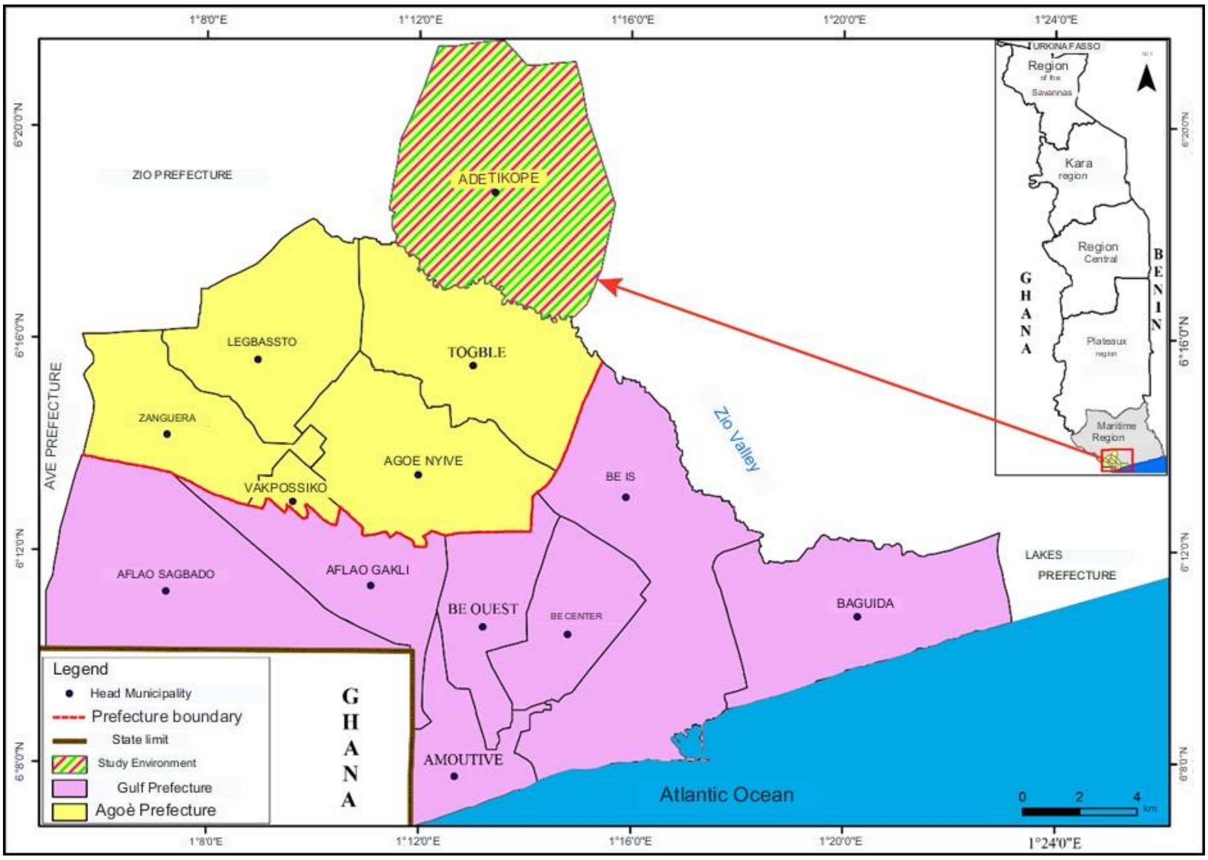

Figure 1. Geographical location of the commune of Agoè-Nyivé 6 (Source [26]).

2.2. Scientific Study Framework

The study project was carried out at the Regional Centre of Excellence on Sustainable Cities (CERViDA-DOUNEDON). The household survey was carried out with the support of the Centre for Educational, Societal, Political and Developmental Expertise of the African Institute for Biomedical, Agrifood, Societal and Environmental Sciences (IASBASE). The samples taken were packaged at the IASBASE BioPhyto-Pharma Laboratory. Analyses were carried out at the Microbiology and Food Quality Control Laboratory (LAMICODA), and physico-chemical analyses were performed at the Water Chemistry Laboratory at the University of Lomé.

2.3. Study Material

The material consists of wastewater samples taken in Adétikopé from December 2022 to February 2023. A total of 12 samples (EU1 to EU12) were taken from 12 villages in Adétikopé (Table 1, Figures 2 and 3).

Table 1. Localities of samples and samples taken from wastewater.

Sampling Locations (Villages of Adétikopé)	Source Location	Surrounding Environment	Coded
Tsikplonou	Behind fence of the house	wholesome	EU1
Kpotave	In front of the house	wholesome	EU2
Tounoukoutsi	Behind fence of the house	unsanitary	EU3
Agave	Home	wholesome	EU4
Agotime	In front of the gate	unsanitary	EU5
Kladjeme	Home	wholesome	EU6
Kpokpome Agouté	Home	wholesome	EU7
Lomenyon-Kopé	Behind fence of the house	unsanitary	EU8
Dzové	Home	wholesome	EU9
Devimé	Home	wholesome	EU10
Adoglové	Home	wholesome	EU11
Adetikope Centre	Home	wholesome	EU12

Figure 2. Wastewater sampling in Adétikopé (Photo Terrain, CEESPOD, December 2022).

Figure 3. Sampled wastewater treatment at the laboratory before analysis (Photo Laboratory, CEES-POD, January 2023).

2.4. Analytical Methods

2.4.1. Sampling Method

A total of 12 water samples were collected from various households with suitable sanitation facilities. Sampling was carried out in the household located in the centre of the village according to our pen-toss survey model. For physico-chemical analysis, samples were collected in labelled 5-litre containers and sent to the Water Chemistry Laboratory at the University of Lomé. Water samples were taken in 500 mL sterile glass vials, labelled and placed in an ice box containing cold accumulators before being sent to the laboratory for analysis.

2.4.2. Analysis Methods for Physicochemical Parameters

The analyses focused on the following main parameters likely to characterize these waters [27].

In situ parameters: pH, temperature and electrical conductivity are determined using a multi-parameter analyzer of the Eutech instrument type (Thermo Scientific™, Eutech™ PC 450 Multi-parameter Meter Kit, Catalog No.: ECPCWP45000, Waltham, MA, USA).

Measurement of chemical oxygen demand: The principle of COD measurement involves boiling a sample in an acid medium under reflux for 2 h in the presence of a quantity of potassium dichromate (oxidizing agent), silver sulphate (acting as an oxidation catalyst) and mercury sulphate II (allowing chloride ions to be complexed). The excess potassium dichromate is then measured. The method used is that of the French standard (NF T 90101).

Measurement of biological oxygen demand: The principle of measuring BOD_5 consists of determining the quantity of oxygen consumed after five days of incubation, under test conditions, at 20 °C in a dilute solution of the sample. To determine BOD_5, two measurements of dissolved oxygen must be taken: (1) at time t = 0, at the time of incubation, and (2) at time t = 5 days, after 5 days. BOD_5 is determined by the respiratory method using an INOLAB BOD meter in accordance with the technique described in NFT 90-103 (BOD inoLab® Oxi 7310, Germany).

Measurement of suspended solids: Suspended solids are determined by filtering a volume of wastewater through a cellulose filter (0.45 μM) using the NFT 90-105 method.

Determination of total phosphorus: The concentration of orthophosphates is determined by the colorimetric method by forming a complex with ammonium molybdate and potassium antimony tartrate in an acid medium, in accordance with ISO 6878.

Measurement of dissolved solids, oils and fats: Dissolved solids were determined using a salinometer. Oils and fats were determined by drying at 105 °C.

2.4.3. Methods for Analyzing Microbiological Parameters

Microbiological analyses of wastewater initially focused on the enumeration of thermotolerant coliforms (TC), fecal streptococci (FS) and sulphite-reducing anaerobes (SRSA) [28]. Secondly, pathogenic bacteria were isolated, purified and identified.

Enumeration: Microbiological analysis of the samples was carried out as soon as they were received in the laboratory in order to avoid any possible change in the initial microbial concentration. A series of dilutions were made in sterile distilled water. Only the 10^{-2} and 10^{-3} dilutions were used to count the fecal contamination indicators (CT and SF).

Enumeration of fecal contamination indicators: The search for and enumeration of TCs and SFs were carried out using the liquid enumeration method by determining the most probable number (MPN). The enumeration results were determined using the Mac Grady table (Rodier, 2009) [29].

Detection and enumeration of thermotolerant coliforms: Colimetry consists of detecting and enumerating coliform germs, including TCs. It is carried out in two stages: (1) presumptive detection of coliforms on Bromocresol Purple Lactose Broth (BCPL) medium and (2) confirmatory testing for TC on Schubert medium [19].

Enumeration of fecal streptococci: FS are enumerated in liquid medium using two culture broths (Rothe medium and Eva-Litsky medium). This method uses two consecutive tests: a presumptive test followed by a confirmatory test [30].

Enumeration of anaerobic sulphite-reducing bacteria: ASR are Gram-positive bacteria that develop over 24 to 48 h on liver agar (VF), producing typical colonies that reduce the sodium sulphite (Na_2SO_3) present in the medium to sulphide, which in the presence of Fe^{2+} produces black FeS (iron sulphide). The spores of RSAs are generally indicators of past contamination [3].

Isolation of *Salmonella* Spp: The agars used are Hektoen and Salmonella–Shigella (SS). Streak plating on Petri dishes is most often used for isolation purposes. The inoculum is taken directly from the water to be analyzed, deposited on a peripheral point of the agar and then streaked over the entire surface. The plates are coded and then incubated at 37 °C for 24–48 h [20].

Purification: Once isolated, the strains are purified by successive subculturing onto the appropriate isolation medium [31].

Identification: Isolated and purified bacterial colonies are seeded on selective culture media (Hektoen, SS). Identification is then carried out using the Api 20 E plate system (Biomérieux, France). It is based on the assimilation of 12 carbon sources and the use of 8 biochemical tests by Gram-negative enteric and non-enteric bacteria. Identification is carried out using API WEB [20].

2.4.4. Processing Statistical analysis of data

The tabulation of the survey forms was carried out both manually and computerized using Excel 2016 (Microsoft Office 365). Descriptive statistics were performed using one-way ANOVA, as the analyses focused on a single variability factor. The ANOVA test was applied to the factors or indicators of variability (physico-chemical and microbiological parameters of the wastewater) as well as the levels or modalities of variability (temperature, pH, germs, etc.) of the categorical explanatory variables (sanitary quality of domestic wastewater in Adétikopé), which would explain the explained variable (sustainable development of Adétikopé through sanitary safety of households).

From an inferential statistics point of view, the data collected were entered and formatted in accordance with EPI info version 6.04 fr of April 2001 developed by CDC Atlanta, a software package used to perform all processing and analysis. The values obtained were compared using the significance level p. Values of $p < 0.05$ are considered significant, and values of $p < 0.01$ are considered highly significant. Values are expressed as mean value ± standard deviation. The axes of these statistical treatments were descriptive statistics of socio-demographic parameters (ethnic group, level of education, age and gender), hierarchical classification on multivariate component analysis (analysis of physico-chemical and microbiological analysis categories) and descriptive statistics of the groups obtained (Me: mean, CV: coefficient of variation), respectively, to test and describe the variation in the values obtained.

The following assumptions were made: (1) Assumption H0: no significant variation between the percentages compared; (2) Assumption H1: there is a significant variation between the percentages compared.

The probability value p' is given by the Epi info6 software. The decision and conclusion are as follows: (1) If $p' < p$, then H1 is accepted, and it is concluded that there is a significant variation between the compared percentages of the values. The value may have a significant increase or decrease in relation to the target value. (2) If $p' > p$, then reject H1, and it is concluded that there is no significant variation between the percentages of the values compared.

Percentage comparisons are made on a sample-by-sample basis and between sampling sites. Epi info6 does not give the probability value α' when the percentage of modalities is obtained on a small number of populations ($n = 5$).

2.4.5. Ethical Considerations

The survey authorizations were issued by the authorities of the Regional Centre of Excellence on Sustainable Cities in Africa (CERViDA-Dounedon) (CERViDA-Dounedon) of the University of Lomé and the Town Hall of Commune Agoè 6, which helped to reassure the households. The household survey was administered with the consent of the respondent. Measures were taken to guarantee the confidentiality of the identity of the households to be surveyed. In addition, the survey was conducted with strict respect for the population and its cultural values, with a translation of the questionnaire into the local language for those who had difficulty with French.

3. Results

3.1. Physicochemical Parameters

Before wastewater is discharged into the natural environment, it must comply with standards established to protect the receiving environment from all types of pollution. The results of the physicochemical parameters of the wastewater sampled are presented in Table 2.

Temperature: During this study, temperature values varied between 30.1 °C and 31.8 °C. The highest temperature values were recorded for sample EU11, while the lowest value was detected for sample EU1. The average temperature values detected during our study were below 35 °C, considered to be an indicative limit value for water intended for crop irrigation.

pH: The pH values of the water samples taken were neutral and varied between 6.87 and 7.20. Acidic values were obtained for EU 5, 6, 8, 10 and 11; neutral values were obtained for EU 3, 9 and 12; and basic values were obtained for EU 1, 2, 4 and 7.

Conductivity: Generally speaking, the conductivity values detected vary between 2160 µS/cm and 6390 µS/cm.

Chemical oxygen demand: The highest COD concentrations were recorded at EU11, with a value of 900 mG/L. This is still within the standard set at 120 mG/L, which is considered to be the limit value for direct discharge from wastewater treatment plants.

Biological oxygen demand: The maximum BOD concentrations detected at 5 were 205 mG/L.

Suspended matter: The results obtained show that the raw wastewater is characterized by fairly high concentrations of the suspended matter: 1053.5 mG/L. The TSS levels recorded in the wastewater do not comply with FAO standards, which are set at a maximum of 30 mG/L.

Total phosphorus: The highest concentration detected was 22.4 mG/L.

Table 2. Individual values, minimum, average and maximum values for physicochemical parameters in sampled wastewater.

Physico-Chemical Parameters	**EU1**	**EU2**	**EU3**	**EU5**	**EU6**	**EU9**	**EU4**	**EU7**	**EU8**	**EU10**	**EU11**	**EU12**	**Minimum**	**Average ± SD**	**Maximum**	***p* Values**
Temperature (T) °C	30.1	30.4	31.0	30.9	31.4	30.8	30.3	30.2	31.2	31.2	31.8 *	31	30.1	30.86 ± 0.52	31.8	$p < 0.05$
pH	7.22 *	7.18	7.01	6.96	6.87	7.03	7.20	7.20	6.99	6.99	6.91	7.05	6.87	7.05 ± 0.12	7.20	$p < 0.05$
Cond elec 20 °C—µS/cM	2180	4180	3660	2270	2300	6390	2160	4200	3640	2300	2340	6410 *	2160	3502.5 ± 1569.43	6410	$p < 0.001$
Dissolved solids—mG/L	1559	2989	2617	1623	1645	4569	1539	3009	2597	1653	1685	4589 *	40	74.25 ± 61.60	205	$p < 0.001$
Suspended solids (SS)—mG/L	410.0	542.9	2080 *	600	590	900	408	544.9	2078	630	630	920	660	793 ± 73.34	900	$p < 0.001$
D. oxygen chemistry (COD)—mgO/L_2	800	820	660	780	860	-	820	800	680	810	900 *	-	408	1053.5 ± 590.07	2080	$p <0.05$
D. Oxygen biol. (BOD_5)—mgO/L_2	75.0	40	65	40.0	201	30.0	55.0	60	45	43.0	205 *	32.0	4.5	5.43 ± 6.53	12.87	$p < 0.001$
Total phosphorus (Pt)—(mgP/L)	10.2	22.4 *	17.9	11.7	5.9	4.5	10.4	22.2	18.1	12.0	6.3	4.7	1559	2506.17 ± 1122.35	4589	$p < 0.001$
Kjeldahl nitrogen (NTK)—mgN/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oils and greases (HG)—mG/L	14.8	<5.0	12.0	<5.0	20.0	59.0	14.6	5.2	11.8	5.3	20.4	61.0 *	<5	22.41 ± 20.46	61.0	$p < 0.001$

* Comparison model value (p <0.05: significant difference; p < 0.001: very significant difference).

Dissolved solids, oils and greases: The average concentration of dissolved solids was 2506.17 mG/L, with extreme values of 1539 and 4589 mG/L. The oil and grease content of wastewater from the Adétikopé locality varies from values < 5 to 61 mG/L.

3.2. Bacteriological Parameters

Enumeration: The enumeration results obtained during our study period show that the CT, CF and SF concentrations recorded in the water samples are very high and vary, respectively, between the plant inlet, the clarifier outlet and the plant outlet.

Search for and enumeration of thermotolerant coliforms: Figure 4 shows the results of TC enumeration. The highest levels of these germs were detected in the samples taken at Dévimé and Tnoukoutsi, with values of between 68.000 CFU/100 mL and 65.000 CFU/100 mL, respectively. The lowest values were obtained in the wastewater from the Adétikopé Centre and Kladjémé, with values of <1 CFU/100 mL. The high concentrations detected at Dévimé and Tonoukoutsi show that the raw water is highly contaminated with human and animal fecal matter.

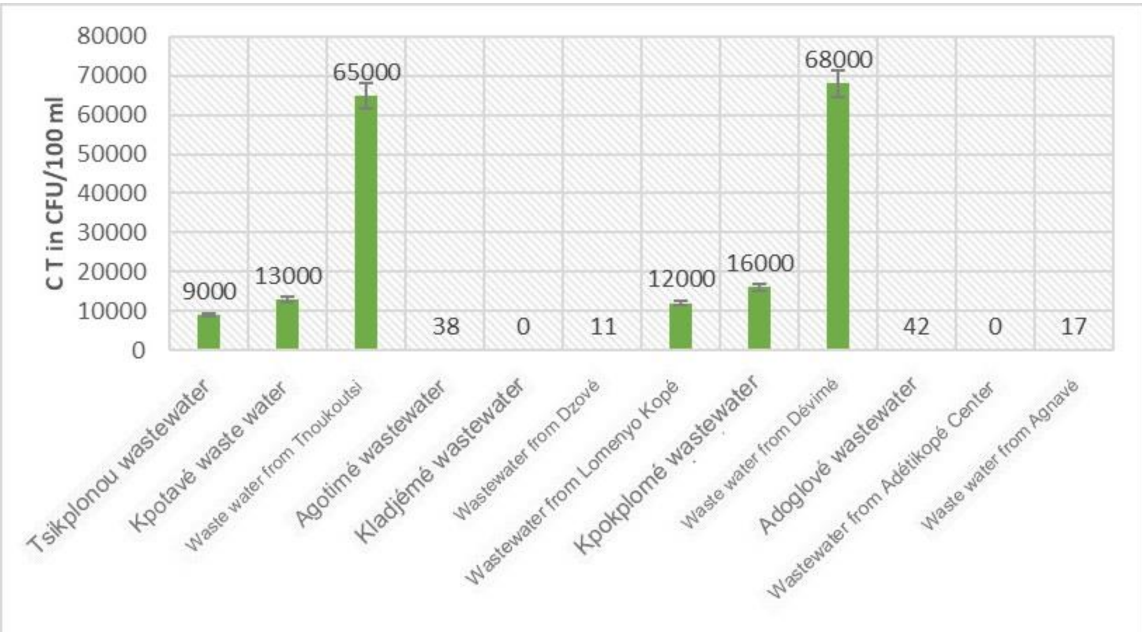

Figure 4. Results of the thermotolerant coliforms (44 °C) count in sampled wastewater (microbiology).

Research and enumeration of *fecal streptococci*: Figure 5 shows the results of the SF enumeration of the wastewater sampled. The maximum detected values of these germs were 47.000 CFU/100 mL and 45.000 CFU/100 mL in Loményokopé and Tsikplonou, respectively. The lowest concentrations were recorded in the wastewater from Adzové and Agnavé.

Determining the origin of fecal contamination: The origin of fecal contamination is determined by the quantitative ratio R = CT/SF. According to the criteria defined by Borrego and Romero in 1982, contamination is of animal origin if the R ratio is less than 0.7 and of human origin if R is greater than 4. The origin of the contamination is predominantly animal if R is between 0.7 and 1, uncertain if R is between 1 and 2, and predominantly human if R is between 2 and 4 [3]. The values obtained for the CT/SF ratios are presented in Table 3. The results obtained showed that the origin of fecal contamination is both animal and human.

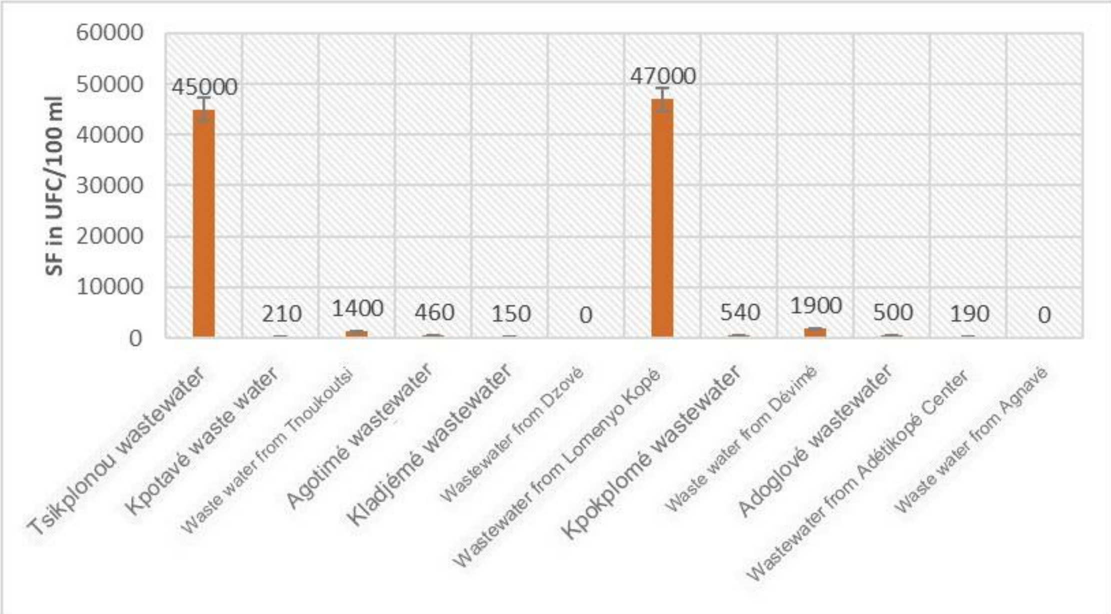

Figure 5. Results of the fecal streptococci (37 °C) count in sampled wastewater (microbiology).

Table 3. Origin of fecal contamination in raw wastewater samples.

Period	CT/SF	Origin of the Contamination
Wastewater from Tsikplonou [EU1]	0.2	Animal origin
Kpotavé wastewater [EU2]	61.90	Human origin
Tnoukoutsi wastewater [EU3]	46.43	Human origin
Agotimé wastewater [EU4]	0.08	Animal origin
Kladjémé wastewater [EU5]	<0.7	Animal origin
Wastewater from Dzové [EU6]	1.94	Origin uncertain
Wastewater from Lomenyo Kopé [EU7]	0.08	Animal origin
Wastewater from kpokplomé [EU8] [FR	>4	Human origin
Dévimé wastewater [EU9]	35.79	Human origin
Adoglové wastewater [EU10]	0.08	Animal origin
Wastewater from Adétikopé Centre [EU11]	-	Origin uncertain
Wastewater from Agnavé [EU12]	>4	Human origin

Research and enumeration of sulphite-reducing anaerobes: The maximum values of these germs detected in wastewater are very low, whatever the type of sample.

Research and enumeration of *Salmonella* spp.: *Salmonella* spp. was not detected in the wastewater analyzed.

4. Discussion

The results of microbiological and physico-chemical analyses of wastewater from the commune of Adétikopé show a diversity of parameters that has been commented on in previous studies of wastewater. The average values obtained show significant differences between them ($p < 0.05$). With regard to physico-chemistry, temperature is an important abiotic factor. Its measurement is necessary, given the role it plays in the solubility of gases, the dissociation of dissolved salts and the determination of pH [32]. Increasing this parameter promotes self-purification and increases the rate of sedimentation, which is of interest in wastewater treatment plants. In addition, temperature accelerates chemical and biochemical reactions [33]. Although the temperature values are below the proliferation limit for microorganisms, there is a significant difference between the waters analyzed, depending on the location ($p < 0.05$). pH influences most chemical and biological mechanisms in water. This parameter is an important element in the interpretation of corrosion in the pipes of wastewater treatment plants [3]. The results showing an average neutral pH ($p < 0.05$) are in agreement with those obtained by other authors [34,35]. These values are also close to the quality standards for irrigation water [36]. The electrical conductivity value is probably one of the simplest and most important for monitoring wastewater quality. It reflects the degree of overall mineralization and provides information on the salinity level [3]. These results show a high level of mineralization, mainly due to the organic load [37]. A comparison of the electrical conductivity values of the wastewater analyzed with the quality standards for water intended for irrigation leads to the conclusion that this wastewater is not acceptable for irrigation purposes [36]. COD corresponds to the quantity of oxygen consumed chemically to oxidize all the oxidizable matter present in the water. COD is particularly suitable for measuring the pollution of industrial effluent [29,37,38]. BOD expresses the quantity of oxygen required for the destruction or degradation of organic matter in water by microorganisms in the environment. This parameter is a good indicator of the biodegradable organic matter content of water during self-purification processes [39]. The COD/BOD $ratio_5$ reflects the fraction of easily biodegradable matter among all the oxidizable matter. The study shows a COD/BOD biodegradability $ratio_5$ for raw wastewater of 10.68, which is greater than 2.5. This result leads to the conclusion that the effluent studied, even though it is domestic, is not predominantly domestic, which could be explained by the presence of numerous industries that pollute surface water. In addition, the value of the TSS/DBO $ratio_5$ obtained is high compared with the usual ratio, which is between 1.2 and 1.5. These high values could be explained by the fact that suspended solids do not sediment quickly upstream of the discharge points, thus causing an increase in their content in the effluent; this increase is all the greater as the discharge flow rate is high. However, maintaining a high concentration of organic matter in wastewater considerably hampers the effectiveness of treatments designed to eliminate pathogens. While the quality standards for wastewater intended for irrigation set a limit value for suspended solids, the same is not true for BOD_5 and COD, for which no limit value is mentioned [40–42]. The results obtained from the wastewater ratio ($p < 0.05$) indicate that this water is poorly biodegradable, as reported in certain studies [43]. TSS represents all the mineral and organic particles contained in wastewater [44,45]. The abundance of TSS in water favours a reduction in luminosity and lowers biological production, due in particular to a drop in dissolved oxygen following a reduction in photosynthesis. Most organic phosphorus comes from detergents, protein metabolism waste and its elimination in the form of phosphates in human urine [44,45]. The increase in total phosphorus concentration is due to the extensive mineralization of organic matter. Conductivity values indicate poor-quality water, which should be treated with caution. The results obtained following analysis of the physico-chemical and bacteriological parameters of wastewater from the Adétikopé locality show two groups of parameters according to their statistical significance. Concentrations of the various parameters investigated varied from one locality to another but were generally higher than the guide value recommended by international standards but lower than those found in some similar studies [30,35,46]. With average pH values obtained that are close to neutral and acceptable for irrigation, the results of this study are comparable with those reported in other studies on physico-chemical and bacteriological studies of raw wastewater from cities undergoing change in Morocco [47–52]. Examination of the results also shows that the pollution parameters in the wastewater of the Adétikopé locality have values comparable to those of cities undergoing demographic change in Africa [34,35,45]. Given the concentration of raw wastewater, its direct discharge into the environment could lead to physico-chemical and biological clogging of the soil, essentially due to the presence of suspended solids, the precipitation of salts and the growth of algae on the surface of the irrigated soil. As a result, the wastewater studied, given its physico-chemical and bacteriological load, should not be reused directly. Treatment prior to any irrigation should be considered in order to improve its quality to the required standards and meet the expectations of consumers and public authorities in terms of environmental and human health protection. With this in mind, an optional lagooning process or, where appropriate, a high-yield lagooning process could be an alternative to reusing this water in its raw state.

From a microbiological point of view, the results of the fecal contamination germ count are not in good agreement with bibliographical data on the state of bacterial contamination of urban effluents [29,53,54]. The results far exceed the standard set by the World Health Organization at 1000 TC/100 mL [53,55–57]. There were significant differences in the levels of microorganisms detected in the samples ($p < 0.05$). TCs are used as indicators of the microbial quality of water and can be indirectly associated with pollution of fecal origin [58–60]. The decrease observed at the Adétikopé Centre and Kladjémé sites is thought to be due to a combination of certain conditions that are unfavourable to them and that are more pronounced in summer: (1) The temperature of the environment has a direct effect on the survival of microorganisms because the rate of elimination of bacteria increases with temperature due to an increase in their metabolic activity [61]; (2) UV radiation can have a direct effect on the elimination of indicator germs through its photochemical action, inducing damage to the genetic material of cells and thus preventing their reproduction [62]. The levels of TC obtained in wastewater exceed the concentration limit (1000 germs/100 mL) recommended by the WHO for the reuse of this water in irrigation [63]. Streptococci are likely to contaminate water supplies and are typical of animal feces. They can sometimes be present in humans or in plants [64]. The high concentrations of streptococci recorded at Loményokopé and Tsikplonou reflect the resistance of these germs in the aquatic environment containing final waste. The decrease in these germs detected at Adzové and Agnavé is thought to be due to the purification system [3]. The presence of ASR indicates the presence of iron sulphite, which causes bad odours and can be the cause of pipe corrosion [29]. These germs are often considered to be indicators of fecal pollution. The spore form, which is much more resistant than the vegetative forms of fecal coliforms and fecal streptococci, can be used to detect old or intermittent fecal pollution. The search for pathogenic germs is often justified by the presence of very high numbers of total germs. Salmonella can be altered in the aqueous environment by heat, and detection in water would require pre-enrichment (ISO 19250). However, it should be noted that pH values below 5 or above 8.5 affect the growth and survival of microorganisms [65]. As far as microbiological parameters are concerned, it is important to consider taking appropriate measures to avoid large-scale contamination in the event of drainage by river water, which could affect human health or the evolution of flora [66,67]. In view of the results and the observation of daily household life, and taking into account the technological prowess, education in this area is needed at the household level in Adétikopé with a view to improving wastewater management practices [68]. One essential point that must be taken into account in this education is its suitability for the population's level of education [69].

5. Conclusions

Adétikopé is an urban centre where strong demographic growth, massive urbanization and the development of industrial and household activities have generated a large amount of wastewater, which can be a source of disease for the people of the Agoè-Nyivé 6 commune. Treated and raw wastewater and sewage sludge are at the origin of various sources of environmental pollution, particularly in developing countries that are less concerned about and less aware of the concomitant health risks. The aim of this study is to assess the physico-chemical and bacteriological composition of wastewater discharged by households in Adétikopé. The results of the physico-chemical parameters showed that the wastewater samples were polluted by numerous organic and inorganic micropollutants. Evaluation of the physico-chemical parameters relating to wastewater from the Adétikopé locality revealed a range of information. The presence of suspended solids in effluent in quantities exceeding the standard recommended by the WHO (30 mg/L) can lead to soil clogging, with harmful consequences for crops. On the other hand, the presence of organic matter in wastewater contributes to soil fertility. Considering the concentrations of the various physico-chemical parameters of wastewater in commune 6 of the Agoè-Nyivé prefecture, the results of the physico-chemical study show that the Adétikopé locality had a high pollution load for most of the study period. The microbiological results show that the raw wastewater from Adétikopé is highly contaminated with bacteria and is not recommended for irrigation. The diagnosis of wastewater quality shows that domestic effluent is the main source of pollution. The parameters of nitrogen, phosphorus, particulate and bacteriological pollution in the water are fairly high, exceeding the admissible levels set by the FAO and WHO. Good use of water and good management of wastewater means that diseases can be properly treated. While a short-term solution would be to disinfect household sanitation systems on a daily basis, in the long term, the construction of collective sanitation systems, backed up by environmental education, remains a sustainable solution for successful sanitation and health safety.

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