The Effect of Wet Coffee Processing Plant Effluent on Physicochemical and Bacteriological Quality of Receiving Rivers Used by Local Community: Case of Aroresa District, Sidama, Ethiopia

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The Effect of Wet Coffee Processing Plant Effluent on Physicochemical and Bacteriological Quality of Receiving Rivers Used by Local Community: Case of Aroresa District, Sidama, Ethiopia

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ABSTRACT: Freshwater bodies such as lakes, rivers, and their biodiversity are being threatened with water pollution from industrial effluents and household sewages. The main objective of this study is to assess the effects of wet coffee processing plants effluent on the physicochemical and bacteriological properties of receiving rivers. Four rivers and 4 sampling points of the selected rivers were included in the study. Focus group discussion and interview were employed to gather primary data. The result showed that parameters of water quality for downstream of the rivers were significant, particularly in the dry season with BODs ranging from 45 ± 1 to 782.6 ± 97 g/ml, COD ranges from 71 ± 21 to 1072 ± 183 g/ml, Conductivity ranges from 75.5 ± 6.6 to 943 ± 56.3, Turbidity ranges from 7 ± 0.43 to 105 ± 6.2, TDS ranges from 62 ± 6.4 to 1059.6 ± 121 g/ml, temperature ranges from 20.1 to 33 ± 1, T. coli form ranges from 77 ± 1.1 to 493 ± 66 and *E. coli* ranges from 28 ± 1 to 213 ± 41 were significantly higher and DO ranges from 2.6 ± 0.15 to 6.1 ± 0.78 g/ml, NH_4 ranges from 1.85 ± 0.4 to 3.3 ± 0.5 g/ml, and pH ranges from 3.6 ± 0.2 to 7.3 ± 0.45 were significantly lower. Most of the samples taken from wastewater and downstream parts of the river showed high level of water contaminants that are significantly greater than the EEPA discharge limits for surface water. Moreover, the qualitative data indicated that the community was affected by bad smell and color change on rivers, skin irritation, malarial case in human due to coffee processing plant effluents. Therefore, coffee processing plants should treat their effluents before they discharge it into the rivers. Responsible government bodies should authorize activities of coffee processing plants in line with the regulations set for environmental safety.

KEYWORDS: Bacteriological quality, coffee processing plant, effluent, physicochemical property, water quality

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Introduction

Human fresh water demand for domestic, industrial, and agricultural purposes is increasing,[1] and access to safe and usable water in most parts of the world is becoming insufficient. Globally, people living under water-stressed condition ranges from 1.4 to 2.1 billion.[2] The majority of population in developing countries have no access to clean water and any form of sanitation services. Consequently, millions of people are suffering from diseases related to water, sanitation, and hygiene, such as diarrhea, skin diseases (eg, rush, athlete's foot), and trachoma.[3] Unsafe water, inadequate sanitation, and poor hygiene are linked to 88% of diarrhea cases worldwide.[4]

Physicochemical and biological water quality indicators are affected in various ways. The main causes of water quality degradation are anthropogenic. Agricultural activities, industrial, mining, fishing, sewage discharge, deforestation, and other commercial activities are some of the human-induced factors that affect the quality of water for various purposes. These activities exacerbate water pollution and have a significant impact on water quality.[5,6]

Because coffee processing industries are significant users of water and produce large amounts of wastewater containing high concentrations of organic matter, nutrients, suspended matter, and highly acidic wastewater, they have a very high pollution load.[7] Thus, considering the volume generated and the pollutants released through the wastewaters, the coffee processing industry represents one of the main contributors to the severe pollution problems and it is reported that they do not have any effluent treatment plants. They directly discharge untreated colored and acidic effluent into the nearby water bodies, streams, and open land.[7]

South Ethiopia is a well-known coffee-growing region in Ethiopia. It has a number of wet coffee processing industries situated along the bank of rivers or streams. Due to poor government oversight and corruption, wastewater effluents are discharged into nearby surface waters with no regard to a sound environmental ethics. It may also infiltrate into ground water and become the main threat to both ground and surface water qualities.[7] With these ground it is important to characterize the coffee processing wastewater and assess the effect of coffee processing plant effluent on the physicochemical and bacteriological properties of receiving water bodies in selected site in Sidama, Ethiopia. Therefore, the main aim of this study was to assess the pollution load of the effluent from coffee processing plant, its effect on nearby water sources and the communities residing in its vicinities.

Material and Methods

Description of the study area

The study was conducted in Aroresa woreda Rivers, in Sidama, Ethiopia. The town is located about 554 km away from Addis Ababa and 181 km from the regional capital city, Hawassa. Aroresa woreda is located at 6°19′60″N longitudes and 39°18′30″E latitude and lies at an altitude of 1800 m above sea level. The mean annual temperature of the area is 30.2°C and the mean annual rainfall is 1333 mm. The study area was mapped using Geographical Information System using information obtained by GPS. Biasa gudu, Lodoma, Meleya, and Kedela Rivers are located near to Lake Genale in the upper Gidabo river basin, not far from the source of the Ganale dorya and Dawa Rivers.[8] The water quality of Aroresa Woreda River was studied on the basis of its agricultural and domestic activities (drinking, washing etc.); as coffee processing industries are discharging the wastewater in to the river.

Aroresa is one of the Woredas in Sidama region. The current population of the Woreda is estimated to be 220,332 of which the rural population comprises 418 135 and urban population of 18 537. Estimated population of Aroresa woreda is 194 835 consisting of 95 469 men and 99 366 female. The total area of the Woreda is estimated to be 640 km^2. In Aroresa there are 3 distinct agro-ecological zones; 12% of the Woreda is classified as Dega (highlands), 71% as Woina dega (midlands), and 17% dry Kolla (lowlands) situated about 7000 feet above sea level Mixed type of farming is the main source of income. The main economic activities of the town are cash crop mainly coffee, agro processing industry (Dry and wet coffee processing industry) and small and medium trade as well as commercial activities.[8] The major types of crops grown include maize, haricot bean, root crops (sweet potato, and enset) and cash crops such as coffee, khat, and fruit trees. Coffee, enset, and fruit are perennial crops in the area and their productivity and production depends on the availability of the required amount of rain in addition to other required inputs. This study was conducted from August 2012 to December 2013. During the whole study period, the primary data (3 days of a week from the chosen sampling points) where be collected through direct measurement of river water quality parameters of the selected study sites in situ and under laboratory condition.

Research and sample design

A descriptive longitudinal study was conducted in order to characterize, measure, compare, and evaluate the effects of wet coffee processing plant effluents on physicochemical properties of the receiving rivers. Four rivers (Table 1) were selected on the basis of differing effluents disposal generated from coffee processing plants activities.[7] These rivers were selected to represent different ecological and environmental variations within each river, in order to understand the influences of effluent discharge by coffee processing plants induced stress on physical, chemical, and biological attributes of the river water quality.

Table 1. Name of river water with number of wet coffee processing plants in sampling sites.

NO.	NAME OF RIVERS	PRIVATE OWNERS	GOVERNMENT	SAMPLE SITE
1	Bias gudu	Weru	—	4
2	Lodoma	Kumlachew	—	4
3	Kedela	Mulugeta	—	4
4	Meleya	—	Government	4
Total				16

At each sampling river, 4 sampling points, that is, discharge point (EP) (where the coffee wastewater enters each river), upstream (UP) (river water above the discharge point) and downstream (DS1 and DS2) (river water below the discharge point) were used for water sampling. Therefore, the sampling stations were designated as US, EP, DS1, and DS2. US were the upstream station used as a reference point or a pristine habitat (Control sites without any impact from the effluent and other possible pollutants because of their location above processing stations). It was located 500 m above wet coffee processing effluent discharge points. EP was located at the, discharge point (The point where effluents from processing plants meet with the river water in each river). The other 2 sites (DS1 and DS2) were downstream stations of the rivers located with different intervals. DS1 is located approximately 500 m below the wet coffee processing plants discharge points. DS2 was also located 500 m away from DS1. Two round samplings, that is, before wet coffee processing starts (rainy season) and after the coffee processing time (dry season) were made to show the effect of the wastewater discharge on the target river.[9]

Both primary and secondary data were employed to achieve the objective of the study. The study also used a quantitative and qualitative research approach, which included a questionnaire, an interview, and a focus group discussion to address particular objectives.

Primary and secondary sources of data

Both qualitative and quantitative data were gathered as primary sources. To collect qualitative data directly from respondents, focus group discussions, key partially structured interviews, and on-site observations from field visits were used. The majority of the quantitative data came from on-site measurements of selected physicochemical properties of water and laboratory examination. Secondary data was gathered from a variety of sources, including previous research findings reports, the Internet, and other published and unpublished materials, books, and administrative office records that were deemed relevant and served as cross references to the study.

Data collection tools

Focus group discussion and key informant interview. Participants are chosen because they have particular traits related to the topic of the focus group. To capitalize on this opportunity, Focus group discussion (FGD) held conversations with formal private enterprise. Focus groups are usually made up of 8 to 12 persons. Purposive sampling techniques were used to choose 12 key informants in order to collect specific information through face-to-face interviews. The main informants were chosen based on their knowledge, experience, and involvement in the coffee processing factory. As a result, village elders, coffee processing employees, and agricultural experts/government officials served as information sources.

Site observation. Relevant information was gathered during a field visit to witness wet coffee processing and analyze the current state as well as the threat of pollution on the receiving river and downstream water users.

Water sampling. Triplicate water samples were collected from the 4 sampling points (US, EP, DS1, and DS2) of each sampling rivers using clean and sterile polyethylene plastic bottles. The samples were stored in an ice box and transported to the laboratory of Hawassa University for analysis. The pH, Electric Conductivity, Turbidity, Dissolved oxygen (DO), and Temperature were measured on the site, while Biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved substance (TDS), Ammonia, Nitrate, and Phosphate were analyzed according to the standard methods in laboratory.[10]

Analysis of physicochemical parameters. Following data collection, the samples were carefully transported using an ice box to the Applied Microbiology Laboratory (for bacteriological analysis) and Applied Chemistry Laboratory of Hawassa University (for physicochemical analysis). All the parameters were determined according to the standard methods[10] unless and otherwise stated. COD, BOD, total dissolved solids, nitrate, phosphate, ammonia were analyzed according to the standard methods in laboratory.

Tests for indicator bacteria and biological parameters analyses. The enumeration of indictor bacteria and the presence of pathogenic bacteria from water samples were processed by suspending them with peptone saline solution (0.85% [w/v] saline and 0.1% [w/v] peptone) and filtered through 47 mm diameter and 0.45 µm pore size membrane filter (HAWG04756, Millipore, Cheshire, UK) according to standard methods.[11]

The enumeration of total coli forms and fecal coli forms in water samples were carried out with a membrane filtration as per standard methods for the examination of water and wastewater *Escherichia coli* was enumerated according to ISO 9308-1.[12] The filtrates were placed on an absorbent pad saturated with Membrane Lauryl Sulfate Broth for total coliforms and fecal coliforms (AVONCHEM, Cheshire, UK), and incubated at 37°C for total coliforms and at 44°C for fecal coliforms for 14 to 18 hours. *Escherichia coli* For the filtrates were placed on Tryptone Soya Agar (CM131, Oxoid, England) incubated at 37°C for 4 to 5 hours and transferred to Tryptone. *Entercocci* was enumerated from samples according to ISO 7899-2. The water and sediment samples were placed on Slanetz and Bartely Agar (CM377, Oxoid, England) and the plates were incubated at 37°C for 44 hours. Thus, procedures described in ASTM.[13]

Data analysis. The information collected from both primary and secondary data sources through review of different documents and in depth interviews with key informants, personal observations and experimental analysis were organized and discussed. The descriptive data obtained from the semi-structured interviews and Focus Group Discussions (FGDs) were analyzed by identifying the themes which informed the categories as they emerge from the data. Facts that were extracted from different documents were analyzed thematically and served to compare with study results accordingly.

The water samples in the laboratory were quantitatively analyzed and compared with the WHO and USA EEPA for standards confirmation.[12] Excel spreadsheet and statistical software's (SPSS version, 20) were used for the statistical analyses. Multi factorial analysis of variance (3-way ANOVA at $P \leqslant .05$) was used to assess the significance difference between water quality parameters upstream and downstream of the selected Rivers. Finally, significance tests were performed on the physicochemical and bacteriological parameters between the references and the impacted sites with a post hoc multiple comparisons Turkeys' test.[14] This test was used to determine the significance of differences between group means in the analysis of variance setting, with alpha set at .05. The results of data analyses were presented using Tables and Figures where necessary.

Ethical consideration. The laboratory analysis was conducted in accordance with scientific procedures, and the results were accurately recorded in data collection formats. Based on the research objective, the researcher took specific steps to ensure the participant's consent and that their information was kept confidential. Furthermore, the authors of the books and journals used were properly cited. Scholars, individuals, and organizations who contributed to the study's success were properly acknowledged.

Result and Discussion

Physical characteristics of the rivers

Temperature. Analysis of variance (ANOVA) showed a statistical difference at $P < .05$ in the 4 sites at the dry season with downstream sites have significantly higher mean temperature value than the upstream sites in all the sampled rivers with more significant at river 3 (Table 5). All the temperature values at the EP and DS sites were relatively higher than the reference sites (US) particularly at the dry season than the wet season and did not meet the WHO standard of <15°C. However, the river wise variation was statically insignificant. This increased temperature value at the impacted sites could be attributed to hot water released directly from coffee processing plants without treatment. An increase in water temperature can have a variety of effects, including increased the rate of all chemical reactions, decreased gas solubility, and effects on fish growth, reproduction, and immunity. Furthermore, a decrease in gas solubility and an increase in the rate of chemical reaction demand dissolved oxygen, rendering the water anoxic.

Different studies showed the effect of water temperature in different ways. Drastic temperature changes can be fatal to fish.[15] Higher temperatures lower the dissolved oxygen solubility in the water causing fish kills more likely in the summer months. Temperature affects the growth and reproduction of aquatic organisms. If the temperature gets too high (above 32°C) or too low (below 25°C), the local population of a species decreases.[16]

Total dissolved solid. Solids in the water that remain after filtration and evaporation as residue are called total dissolved solids (TDS) and used as indicator of water quality. In water, TDS are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, potassium and manganese, organic matter salts, and other particles.[8]

In this study there was higher concentration of total dissolved solids at the entry points of the rivers (611 ± 53 mg/l) at river 1 (Table 3), 1054 ± 121 mg/l (Table 4), 1361 ± 11 mg/l (Table 5), and 986 ± 11 mg/l (Table 6), where the river and the effluent mix together followed by the downstream point DS1 (708 ± 71 mg/l) at river 2 (Table 5) and DS2 (453 ± 89.5 mg/l) at river 3 (Table 5) in the dry season. There was significant difference between the reference sites and the impacted sites at $P < .05$ in the dry season. However, mean values of TDS among the upper stream and downstream sites at wet season were not significantly different. Total dissolved solid concentration at the impacted sites EP, DS1 and DS2 at dry season were above EEPA[12] standards for effluent discharges to surface water in all the sampled rivers (Table 5).

It had been reported[8] that the (TDS) is an important parameter in evaluating the suitability of water for irrigation since the solids might clog both pores and components of water distribution system. The TDS present in the water affects its esthetic value as well as its physic-chemical properties. Excess amount of TDS can increase the salinity of the river water that decreases its availability for drinking, irrigation, and other similar purpose by the down-stream users. Report from Gedeo zone[17] also indicates high concentration of TDS and TSS might also lowers the photosynthetic processes and water quality by lowering light penetration potential.[18]

The correct balance of dissolved solids in water is essential to the health of aquatic organisms for several reasons. One of the reasons is that dissolved materials are essential nutrients for aquatic organisms; too much dissolved salts in water can dehydrate aquatic organisms. Too low dissolved salt however, can limit the growth of aquatic organisms that depend on dissolved salts as a nutrient. High concentrations of dissolved solids can lead to unpleasant taste and laxative effects in drinking water (other effects may be: reduced water clarity, decrease in photosynthesis, binding with toxic compounds and heavy metals, and increased water temperature through greater absorption of sunlight).[19] The overall Rivers spatial and temporal variation in TDS is given in Figure 1 below.

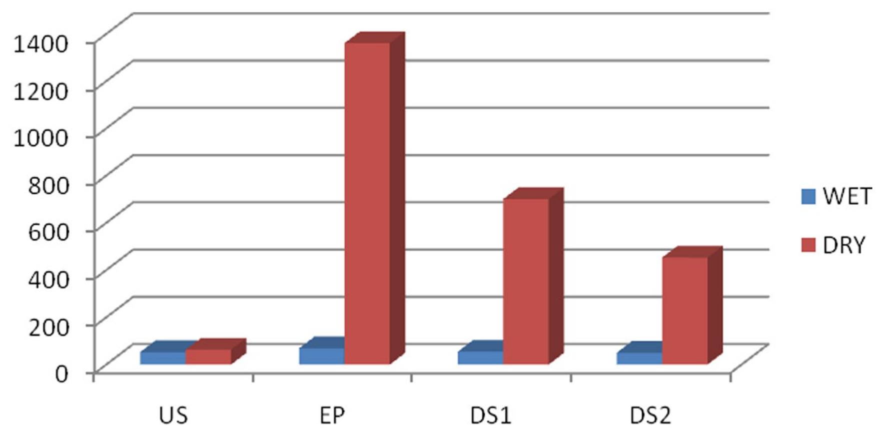

Figure 1. The overall Rivers spatial and temporal variation in Total dissolved solids.

Dissolved oxygen. Analysis of dissolved oxygen between sampling sites showed significant variations both in season and sampling sites. 2.4 ± 0.1 mg/l (EP of river 4) (Table 5) in dry season was the lowest mean value and 7.7 ± 0.9 mg/l (US of river 3) (Table 5) in the wet season were the maximum measured mean value of DO. There was no significant difference

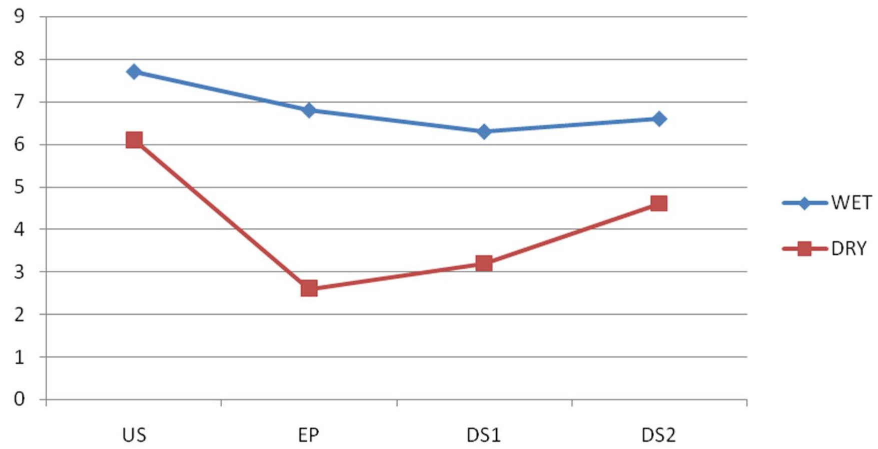

Figure 2. The overall Rivers spatial and temporal variation in dissolved oxygen.

between upper stream parts of the rivers in a dry and wet season but insignificant difference between the sites at the same season and river wise. The impacted sites of all the rivers have lower dissolved oxygen value, below the standard limit of EEPA[12] than the reference sites (upstream) particularly at the dry season where coffee processing intensifies but varies insignificantly at wet season (before coffee processing time) (Table 6). Decomposition and nitrification were the major processes that diminish the levels of DO in rivers that are impacted by the coffee waste. Consequently, low levels of DO reduce the self-purification capacity of these rivers to recover from the coffee waste impact during off season. According to the authors, DO concentrations below 5 mg/l may also adversely affect the functioning and survival of biological communities. Water consisting of high DO is usually considered healthy and capable of maintaining stable ecosystem with many taxa of organisms. However, a fall in DO level is an indicator of organic pollution.[8]

The current finding was similar with the findings of Gebremariam et al[18] from Bonga, zone, Ethiopia and Kebede,[20] from Jima Ethiopia who illustrated that the DO concentrations of their respective study sites were below the standard limit of EEPA.[12] A report from Fikreselasie,[16] described concentration of DO in natural water reduce (depleted) as a result of biodegradation of carbonaceous and nitrogenous wastes discharged into water bodies deposited in the sediment and the point or non-point input of plant limiting nutrients which leads to eutrophication. Because carbohydrates are converted into carbon dioxide and water during aerobic respiration, oxygen demand is relatively high, requiring approximately 1.07 g of oxygen per gram of carbon dioxide. Research findings of Gebremariam et al[18] revealed that, during the peak coffee processing season, the disposed untreated coffee waste consumed DO as a result of high decomposition, which creates anoxic condition and curtailed nitrification. Research findings of Tsegaye,[21] in his study at Chichu River in Gedeo zone also indicates that downstream sites has significantly lower dissolved oxygen concentration than upstream sites particularly at coffee processing times. The overall Rivers spatial and temporal variation in DO is shown in Figure 2.

Conductivity. The ability of water to conduct an electric current is referred to as conductivity, and it is an indirect measure of ion concentration. The more ions present, the more electricity the water can conduct. Sodium, calcium, potassium, magnesium, iron, aluminum, chloride, sulfide, carbonate, and bicarbonate are among these ions. As a result, conductivity rises not only as total dissolved solids rise, but also as water temperature rises.[19]

In this study, electrical conductivity was found to be at the ranges between $75.5 \pm 6.6\,\mu S/cm$ (US river 1) (Table 3) in dry season and $643 \pm 56.3\,\mu S/cm$ (EP river 3) in dry season (Table 5). Analysis of variance (ANOVA) indicates, there was significant difference between the reference site (upstream sites) and impacted site (downstream sites) of the sampled rivers at $P < .05$ at the dry season but the difference was insignificant at the wet season.

The high conductivity value at sample points EP $643 \pm 56.3\,\mu S/cm$ (Table 5), $458 \pm 107\,\mu S/cm$ (Table 6), $438 \pm 48\,\mu S/cm$ (Table 4), and $318 \pm 71\,\mu S/cm$ (Table 3) at rivers 3, 4, 2, and 1, respectively and other downstream sampling points indicates Coffee processing industries release wastes to the rivers and they are responsible for the increasing value of the conductivity at the impacted sites. In all sampling rivers, the concentration of electrical conductivity decreased from sampling sites EP to sampling point DS2, which may reflect the dilution effect of the surface water. Except for the EP and DS sites during the dry season, all of the EC values were within the 15 standards for effluent discharges to surface water (Table 5). The overall Rivers spatial and temporal variation in conductivity is shown in Figure 3.

Turbidity. Turbidity is a measure of the virtual clarity of water. Turbidity in water body is caused by suspended and colloidal matters such as clay, silt, organic material, algae, and other inorganic material. The concentration of turbidity is an indication

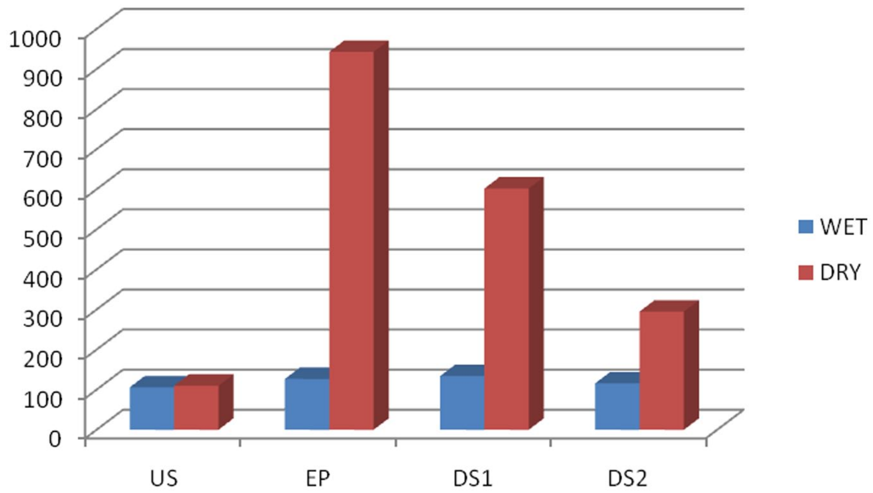

Figure 3. The overall Rivers spatial and temporal variation in conductivity.

that the water is containing other particles than water molecules that contaminate or pollute water bodies. The turbidity of raw water can range from less than one nephelometric turbidity unit (NTU) in very clear water to over 1000NUT in turbid and muddy water.

The current study found that the turbidity of river waters was higher downstream during the dry season, when coffee processing is at its peak. ANOVA analysis of the sites, rivers, and seasons revealed that downstream sites of selected rivers were significantly higher than upstream sites after coffee processing time or dry season, with EP value being the most significant, followed by DS1 and DS2 (Table 5). The rivers mean turbidity value ranges from 6.3 ± 1.5 (DS1 of river 4) (Table 6) to 121 ± 8.5 (EP of river 3) (Table 5). This indicates magnitude of coffee processing wastes that affect the amount of solids of the river water. The average turbidity at the impacted sites (EP and DS) of the selected rivers during coffee processing time was above EEPA[12] standards for effluent discharges to surface water. The overall Rivers spatial and temporal variation in Turbidity is illustrated in Figure 4 below.

Chemical characteristics of the water samples from rivers

Biological oxygen demand. The 5 day BOD is the most widely used parameter of organic pollution applied to surface waters. It is the amount of dissolved oxygen taken up by aerobic microorganisms to degrade oxidizable organic matter present in stream measured over the period of 5 day. BOD normally gives an indication of the amount of biodegradable organic matter.[2]

Analysis of variance (ANOVA) analysis showed significant difference at $P < .05$ in the sampling points at the dry season. Site DS2 river 3 had the lowest mean value of BOD (33.3 ± 13.5 mg/l) (Table 5) during the wet season and site EP river 3 had the highest mean value (782.6 ± 97 mg/l) (Table 5) in the dry season. The sites DS1 and DS2 in all sampled rivers were also characterized by higher levels of BODs concentrations at the dry season due to discharge of organic effluents from coffee processing industries. This indicated that, the coffee processing effluents were loaded with organic and inorganic wastes which require greater amount of DO to be oxidized by microorganisms. Except the upstream sites, BOD concentrations in the downstream sites at dry season were higher than the standard limit. The high levels of BOD were indications of pollution with wastewaters. They also indicate that there could be low oxygen available for living organisms in the wastewater when utilizing the organic matter present.

The results were in good agreement with previous studies on BOD analysis of coffee processing wastes. Research findings of Beyene et al[2] revealed that, the minimum BOD (0.5 mg/l) and the maximum BOD (1900 mg/l) were respectively measured at upstream sites which are free from coffee processing waste impact and from downstream sites receiving coffee processing effluents. Reports from Gebremariam et al[18] described that, values for BOD indicating the amount of oxygen needed to break down organic matter are high in coffee wastewater (up to 20 000 mg l^{-1}) for effluents from pulpers and up to 8000 mg l^{-1} from fermentation tanks. Coffee wastewaters are high in organic loadings and exhibit a high acidity.

According to Tarekegn,[19] the discharge of waste with high level of BOD can cause water quality problems such as severe dissolved oxygen depilation and fish kill in receiving water bodies. Untreated coffee processing plant effluents are known to have high BOD and COD.[7] The presence of high organic matter in wastewater has also an adverse impact on aquatic life. High BOD levels lead to higher consumption of DO by aerobic bacteria robbing the oxygen that other aquatic organisms need to get. Therefore, depletion of DO can cause major shifts in the composition and abundance of aquatic organisms. The overall Rivers spatial and temporal variation in BOD is given in Figure 5 below.

Chemical oxygen demand. The COD is used as a measure of equivalent amount of oxygen required to completely oxidize both biodegradable and non-biodegradable organic and

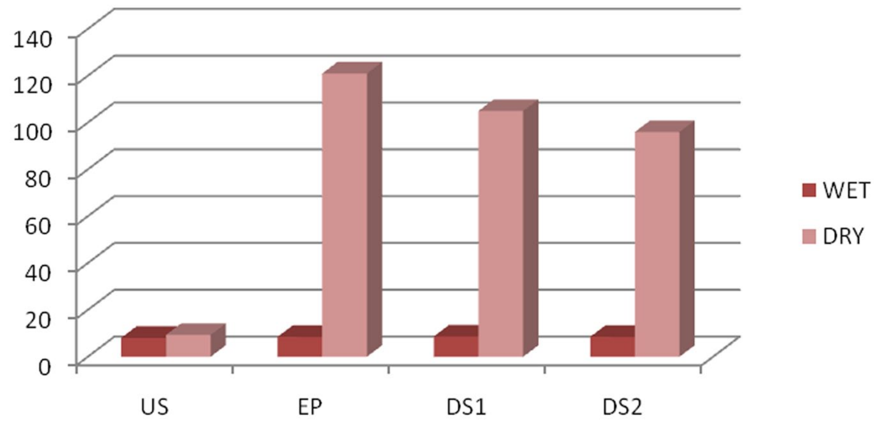

Figure 4. The overall Rivers spatial and temporal variation in Turbidity.

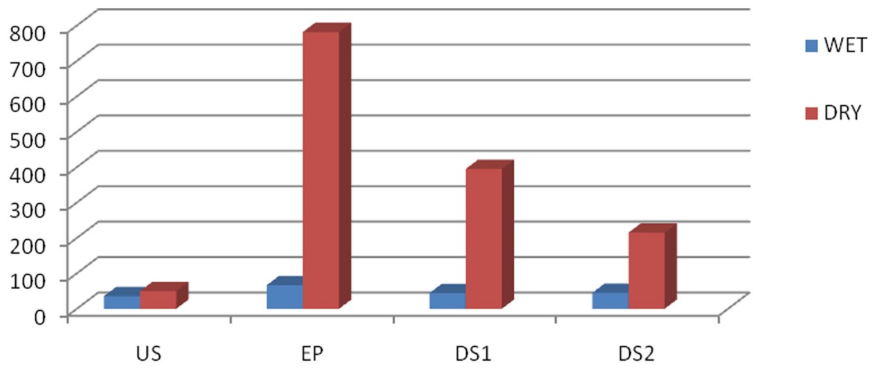

Figure 5. The overall Rivers spatial and temporal variation in BOD.

inorganic matter. It is the measure of the amount of oxygen in water or wastewater consumed for chemical oxidation of pollutants. COD does not differentiate between biologically available and inert organic matter, and it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water.

The findings of the study showed that COD mean values to be in the ranges between 33 ± 1.5 mg/l (DS2) river 2 recorded in wet season (Table 4) and 1072 ± 183 mg/l (EP) river 3 in dry season from the sampled rivers and sites (Table 5). Analysis of variance (ANOVA) also revealed a significant difference ($P < .05$) in mean COD values among upstream and downstream sites at dry season. Sites US were not significantly different from EP, DS1, and DS2 sites in wet season. The maximum amount of COD was recorded in EP of the rivers in dry season where the effluent meets the river followed by sites DS1 and DS2 in all the sampled rivers. The higher level of COD could be due to the discharge of effluent with higher load of organic materials from coffee processing industries.

Findings of Jini and Minuta,[17] revealed that, the organic compounds in coffee wastewater resulted in high BOD and COD. Also, Kebede,[20] reported that, average effluent from advanced coffee processing plants to be (3576 ± 667.7 mg/l) COD. Furthermore, the mean concentration of BOD was 2687 ± 518.04 mg/l which was above the EEPA standards. Similarly, the findings of Woldesenbet et al[22] showed that, the COD of pulp juice and mucilage was 45 000 and 33 600 mg/l respectively which were above the standard limits of EEPA.[12] Reports of Gebremariam et al[18] also indicated the effect of organic wastes as follows; The organic substances diluted in the wastewater breakdown very slowly by microbiological processes, using up oxygen from the water. Due to the decrease in oxygen content, the demand for oxygen to break down organic material in the wastewater exceeds the supply, dissolved in the water, thus creating anaerobic conditions.

Nitrate. The Nitrate concentration depends upon the activity of nitrifying bacteria. The seasonal and spatial difference in nitrate concentration of the selected rivers was significantly different ($P < .05$). The mean value of nitrate ranged between 2.6 ± 0.11 at DS1 of river 1 (Table 3) to 4.9 ± 0.9 mg/l at DS2 of river 2 at dry season (Table 4). All the nitrate values were within the permissible limit given by WHO standards.

Furthermore, findings of Tafesse et al[9] revealed that, excess nitrogen, primarily in the form of nitrates, can cause the stimulation of plankton, resulting in algal blooms or overgrowth of aquatic plants, which can have serious consequence for the receiving water such as odors, accumulation of unsightly bio mass, dissolved oxygen depletion due to biomass decay, and loss of fish and shell fish. The overall Rivers spatial and temporal variation in Nitrate is shown in Figure 6 below.

Ammonia. Analysis of ammonia between sampled points showed significant variations($P \leqslant .05$) with the mean values of ammonia at entry point EP and downstream sites of the selected rivers were significantly lower than the upstream parts at the dry season and insignificant at wet season (Tables 3-6). The mean ammonia values ranges from 1.75 ± 1.5 at EP of river 3 on dry season (Table 5) to 4.8 ± 1 at EP of river 4 on wet season (Table 6).

The presence of significantly minimum level of ammonia at the downstream sites on the dry season when there was intensified coffee processing was due to the lower pH caused by the acidic nature of untreated effluent directly discharged from coffee processing industries. The overall Rivers spatial and temporal variation in ammonia is shown in Figure 7 below.

Phosphate. It is available in the form of phosphate in natural waters and generally occurs in low to moderate concentration. Agriculture runoff containing phosphate fertilizers as well as the wastewater containing the detergents etc. tend to increase phosphate pollution in water. Analysis of variance (ANOVA) for phosphate indicates insignificant variation between the rainy and dry seasons and among the sampling points of the selected rivers. The overall mean phosphate concentration ranges from 1.26 ± 0.26 at US site of river 1 (Table 3) to 2.9 ± 0.54 at EP of river 4 (Table 6) in dry season. Although there was a relative difference between season and sites of the selected rivers were within limits set by EEPA[12] standards for effluent discharges to surface water. This may indicate the sources of pollutants have lower levels of phosphate by nature or the ability of phosphate to sediment water bodies.

Concerning Phosphorous concentration, the findings of Jini and Minuta,[17] and Tsegaye,[21] from Gedeo zone of Ethiopia, and Haddis and Devi[23] from Jima zone of Ethiopia illustrated that the phosphorous concentrations in their study sites were lower than the permissible limit of EEPA[12] but the findings of Tekle et al[7] from Jima zone Ethiopia showed that the concentration of phosphorous of his study sites were higher than the discharge limit of Corro et al[14] From Figure 6, it can be observed that the concentration of phosphates was higher during the dry season than in the wet season.

pH. In the present study, hydrogen ion concentration (pH) values for the downstream lead to be acidic. This difference was significant at the dry season when coffee processing was intensive. The mean values of pH at EP of the rivers relatively acidic (3.6 ± 0.2) (Table 5) 4.3 ± 0.15 (Table 5), 4.3 ± 0.34 (Table 4), and 4.3 ± 0.81 (Table 3) followed by sites DS1 (4.3 ± 0.6) (Table 6), 4.5 ± 0.4 (Table 5), 4.6 ± 0.2 (Table 4), and 4.9 ± 0.7 (Table 3) at rivers 4, 3, 2, and 1 and DS2 (4.9 ± 0.3) (Table 3),

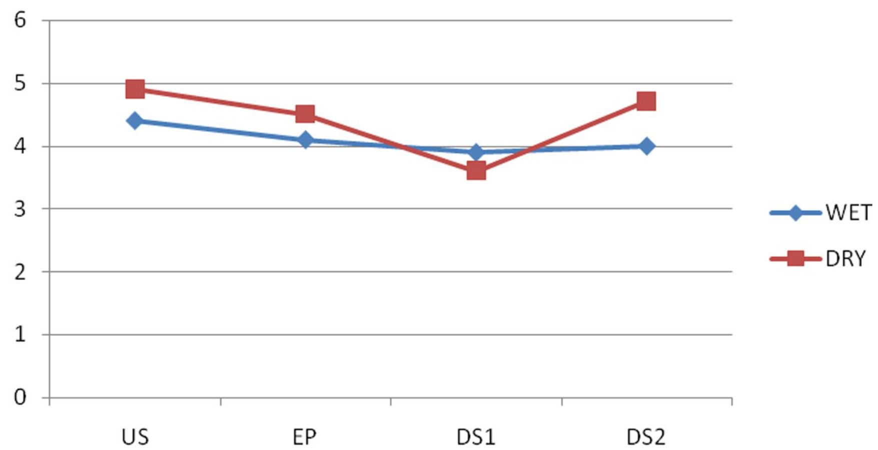

Figure 6. The overall Rivers spatial and temporal variation in Nitrate.

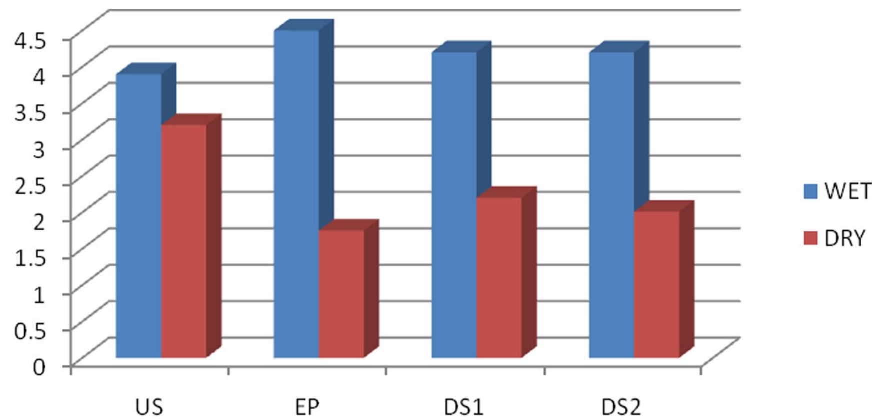

Figure 7. The overall Rivers spatial and temporal variation in ammonia.

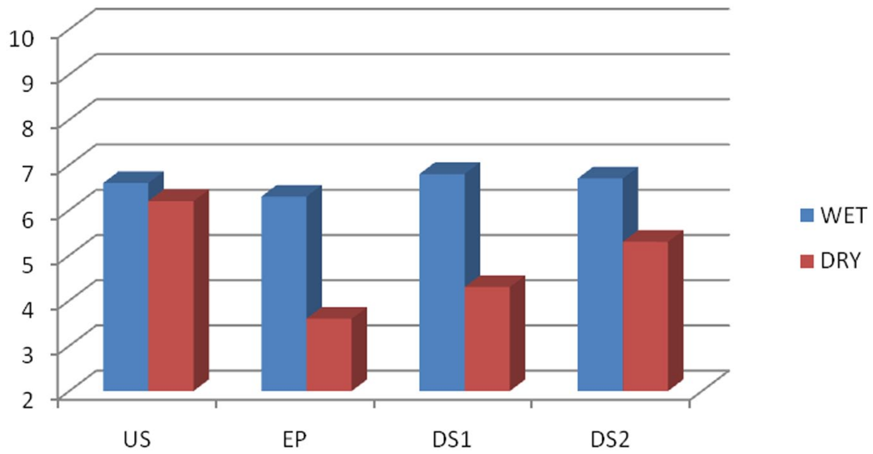

Figure 8. The overall Rivers spatial and temporal variation in pH.

4.9 ± 0.4 (Table 4), 5.3 ± 0.3 (Table 5), and 5.3 ± 0.2 (Table 6) at rivers 2, 1, 3, and 4 respectively. The pH values of these sites were below the permissible limits according to the standards given by Ethiopian Environmental Protection Authority[12] for liquid effluent (6.5-9). The lower pH values at EP and DS sites of the sampled rivers is due to the discharge of effluent from the coffee processing plants near the rivers was slightly acidic in nature. There was a gradual increase in the mean values of pH from sites EP to DS2. This increase could be because of dilution capacity of the river water. Similarly the pH values of sites located at US sides and every site at wet season of each sampled rivers were ranged from (6.2 ± 0.23) at EP of river 3 to (7.6 ± 0.1) at river 2 were above the standards given by Ethiopian Environmental Protection Authority[12] for liquid effluent (6.5-9). Acidic conditions in water can affect life in different ways. For instance the pH of water affects the solubility if many toxic and nutritive chemicals, which affects the availability of these substances to aquatic organisms. As acidity increases, most metals become more water soluble and more toxic.

Similar with the current study, different studies indicated that coffee processing effluents and the condition of water bodies nearby coffee processing plants were acidic. Findings of Kebede,[20] revealed pH 4.3 from water bodies found near conventional wet coffee processing plants after receiving effluent wastewater from these systems. Reports from Beyene et al,[2] also indicated that, coffee waste is known to lower the pH, and acidic waters (pH 4.5) were recorded during the peak coffee-processing season in 2007. According to Tekle et al[7] the pH was found to be high in the upstream (7.11) and reduced pH values were recorded at downstream locations of most rivers (as low as 3.24) having coffee processing plants along their sides. The findings of Jini and Minuta,[17] also showed that the neutral pH mean value is within the range of MPL (7.27 ± 0.13) was measured in the upstream station, where as acidic pH, which were significantly lower than MPL was also measured in the down streams, of Walleme River at Gedeo zone. According to Aklilu,[24] one of the most significant environmental impacts of pH is involvement on synergistic effects. For example, very acidic water can increase the mobility of heavy metals, such as copper and aluminum. The pH value in this study was found to be at a level that supports optimal survival of micro-organisms and this explains the high *coli forms* present. The overall Rivers spatial and temporal variation in pH is given in Figure 8.

Biological characteristics of the selected rivers

Total coli form. The highest TC count was recorded from sampling sites located downstream and EP of coffee processing plants in each sampling rivers. This significant increase in TC count was particularly at the dry season and TC count was statically significant (<.05) among the reference sites and impacted sits in comparison to wet season when there was no effluents discharged from coffee processing plants. The EP of (River 3) had a maximum TC count of 493 ± 66 CFU/100 ml (Table 5), followed by 453 ± CFU/100 ml at EP of river 4 (Table 6).

The lowest TC count was found at DS1 of river 2 with 71 ± 1 CFU/100 ml, (Table 4). Although the TC counts of the rivers water were relatively lower at the reference sites and impacted sites at the wet season than the dry season 100% of the water samples did not meet the TC standard (1-10 CFU/100 ml) set by WHO[25] and failed to meet safe water quality with regard to FC criteria of 0 CFU/100 ml. This indicates the effluents discharged from coffee processing plants have a high load of organic matter which intern leads overwhelming of the river waters with microorganisms. The overall Rivers spatial and temporal variation in Total coli forms is shown in Figure 9 below.

Fecal coli form. ANOVA among the sampled rivers and sampling sites showed significant difference in the FC count at the dry season than wet season. The highest FC count of 213 ± 41 CFU/100 ml was recorded from sampling site EP of river 3 (Table 5) where as lowest fecal coli form (25.6 ± 3.7) was detected from sampling site US of river 1 (Table 3).

All sampling points of the selected rivers showed relatively lower FC count at the wet season or before coffee processing starts and no effluent was discharged. However after coffee processing, the downstream sites of the sampled rivers showed a significant increase in FC count than upper stream or reference sites. This indicates the organic loaded waste discharged from coffee processing plants causes proliferation of microorganisms which may depraves the dissolved oxygen of the river water. Unless the river water was attributed to free residual chlorine disinfection or other treatments, using this type of water for domestic purpose may have devastating health effect on the downstream users.[18] *E. coli* is a major indicator of fecal contamination of water. Therefore, the findings of this study establish that there is sewage contamination of water in the rivers. The overall Rivers spatial and temporal variation in *E. coli* is shown in Figure 10 below.

Environment and biodiversity related problems of coffee processing plants. Regardless of their economic importance, industrial plants are generally associated with the generation and discharge of solid or liquid wastes. Polluted effluents of variant physicochemical characteristics are directly or indirectly discharged into the nearby Rivers and Streams.[26] According to the response of FGDs, the selected rivers had a number of socio economic importance such as esthetics, irrigation, and livestock production. However, sometimes these rivers cannot provide their intended importance's especially after coffee processing time because their quality gets deteriorated by effluents that are discharged without preliminary treatments. The major physical changes were presences of suspended materials, change in color, and bad smell.

Environmental protection officials interviewed about the major environmental effect of coffee processing effluents explained that, despite their economic importance coffee processing plants have a negative impact on the environment and over all biodiversity. They generate solid and liquid wastes which affects the physicochemical and biological characteristics of the environment. Effluents with organic load, suspended solid, and acidic condition were directly released into the nearby rivers. The river water deteriorated and showed physical changes such as change in color and bad smell which makes the water uncomfortable for community use. Moreover, the acidic pH of the effluent kills fish and other invertebrate organisms. The organic load of the effluent also lowers the dissolved oxygen balance of the rivers till they didn't support the life of other organisms.

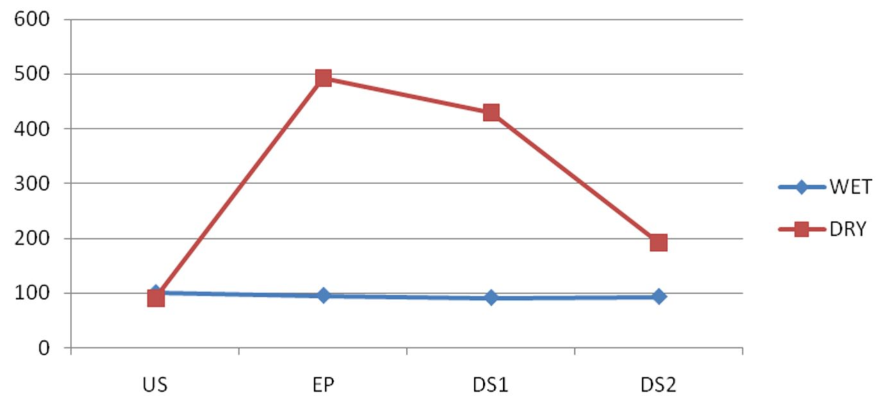

Figure 9. The overall Rivers spatial and temporal variation in *Total coli forms*.

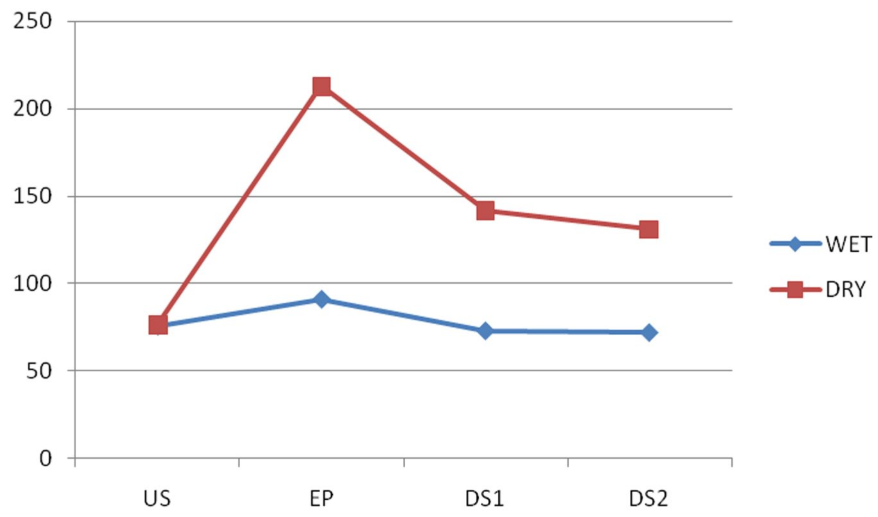

Figure 10. The overall Rivers spatial and temporal variation in *E. coli*.

Table 2. Percentage of populations affected by water associated diseases in Aroresa Woreda health center.

YEAR	TOTAL NO OF POPULATION IN THE ARORESA WOREDA	POPULATIONS INFECTED BY WATER BORN DISEASES	% OF INFECTED POPULATIONS
2009	6217	121	1.9
2010	6743	198	2.9
2011	7190	365	5.07
2012	7321	543	7.4
2013	7896	564	7.1

Similarly, Tsegaye[21] mentioned that, water pollution from wet coffee processing significantly have a negative externality. Byproducts of wet coffee processing plants were organic in nature that ferments rapidly to produce organic acid. Direct discharge of coffee effluents to nearby rivers changes the physiochemical and biological characteristic of rivers water. Beyene et al[2] noticed that poorly designed and constructed pits do not prevent pollution of water bodies and the resulting longer-term threat to aquatic life, human health, and wildlife unless well-designed treatment technologies for coffee waste are used and sound environmental practices are adopted and promoted in the coffee-growing regions of Ethiopia. Local authorities need to take urgent measures to improve the ecological quality of these rivers as part of the efforts to restore their ecology and relieve public health risks.

Human health related problems. Another aspect of this study was to assess the effects of contaminated effluents released from coffee processing plants on the health of people living around the factories (Table 2), especially those living very close to the processing plants and downstream of coffee processing plants. The participants of the FGDs stated that residents who live closer to the processing plants and those who live downstream are more vulnerable than those who live faraway and upstream. Respondents asked if they experienced any health problems because of exposure to coffee processing effluents locally discharged to these rivers. The participants in the FGD explained the major health effects caused by direct contact with the polluted water while they are washing their clothes and on their body was skin irritation and allergy on breathing organs.

The health sanitation expert of the Aroresa Woreda also explained the incidence of health problems were mostly related to skin allergies, malarial cases breathing problems, diarrhea, and abdominal pain. According to the expert explanation, allergies and irritations were closely related with the direct contacts of the patients with the river water polluted with the effluents of high suspended materials and other chemical constituents while the malarial case was caused by the waste which was temporary stored in the pits of coffee processing plants and proliferates mosquitoes. The breathing problems were mostly associated with air pollution caused by dry coffee processing method that releases tiny suspended particles and aerosols while separating the coffee bean and coffee husks.

The data on Table 2 above shows that water borne cases increases from 2009 to 2013 which also supports the idea of the FGDs and the health experts. Similarly, Dori[27] from Gedeo zone indicates that the poor management of the effluent affects human health around the zone through water and air pollution. In fact water is important to living things and people used for drinking and food preparation etc. However, wet coffee processing industry release wastewater to rivers that affects human health through effluents. Likewise dry coffee processing pollutes air through the release of dust particles in the atmosphere that affects human breathing system. Wastewater directly discharged to the nearby water bodies and thus cause many severe health problems, these are spinning sensation, eye, ear, and skin irritation, stomach pain, nausea, and breathing problem among the residents of the nearby areas.

Table 3 below indicates the physicochemical and bacteriological characteristics of Bias Guda River found in Aroresa Woreda. As the findings indicated, most of the parameters like TDS, BOD,COD were above the limit set by EEPA[12] while parameters like DO, pH, and NH_4 were below the standard (Table 3). This shows that the river was polluted by the effluents directly or indirectly discharged from coffee processing plants.

Table 4 below showed that physicochemical and bacteriological characteristics of Lodoma river found in Aroresa Woreda. As the results indicated, most of the parameters of the river like TDS, BOD, COD were above the limit set by EEPA[12] while parameters like DO, pH, and NH4 were below the standard. The overall quality of the river indicates spatial and temporal variation as the sites downstream of the coffee processing plant were significantly harmed than the upper stream parts. This was significantly higher at dry season when coffee processing intensifies. This shows that the river was polluted by the effluents directly or indirectly discharged from coffee processing plants.

Kedela River is found in Aroresa Woreda. As the results in Table 5 indicated most of the parameters of the river, like TDS, BOD, COD were above the limit set by EEPA[12] while

Table 3. Physicochemical and bacteriological characteristics of River 1(Bias gudu).

SEASONS	RAINY SEASON				DRY SEASON			
SAMPLING SITES	US	EP	DS1	DS2	US	EP	DS1	DS2
PARAMETERS	MEAN ± SD				MEAN ± SD			
DO (mg/l)	7.5 ± 0.6	5.5 ± 0.4	6.2 ± 0.3	6.4 ± 0.4	5.9 ± 0.5	2.7 ± 0.1	3.2 ± 0.3	3.9 ± 0.4
BOD (mg/l)	44.8 ± 1.2	37.6 ± 1.6	44.3 ± 4	40.7 ± 1.6	45 ± 15	611 ± 37.3	386 ± 59	274 ± 47
COD (mg/l)	86 ± 2	88.2 ± 11	90 ± 10	88 ± 20	90 ± 2	635 ± 164	565 ± 12	424 ± 29
pH	6.9 ± 0.2	6.9 ± 0.5	6.7 ± 0.6	6.7 ± 0.7	7.3 ± 0.5	4.3 ± 0.8	4.9 ± 0.7	4.9 ± 0.3
TEMP (°C)	22 ± 1	24.1 ± 0.8	25 ± 1.6	24.0 ± 1	20.3 ± 1	28.8 ± 0.2	25.8 ± 0.8	24.9 ± 1
TUR (NTU)	7.8 ± 0.98	7.3 ± 0.9	8.4 ± 1	6.5 ± 0.22	7 ± 0.43	46 ± 4.3	53 ± 16	93 ± 11
COND (µm/cm)	113.3 ± 7	124 ± 1	120 ± 1	117.3 ± 1	75.5 ± 6.6	318 ± 71	181.3 ± 27	184 ± 45
TDS (mg/l)	52 ± 6.4	73.6 ± 8.8	81.1 ± 7	52 ± 3.5	62 ± 6	611 ± 53	295 ± 42	134 ± 14
NH_{4-N} (mg/l)	3.9 ± 0.6	4.5 ± 1	4.2 ± 1.1	4.1 ± 0.8	3.1 ± 0.5	1.9 ± 0.2	2 ± 0.4	1.9 ± 0.4
NO_{3-N} (mg/l)	2.8 ± 0.1	3 ± 0.2	2.6 ± 0.1	3 ± 0.2	4.9 ± 0.6	4.4 ± 1.1	2.9 ± 0.56	4.8 ± 1.5
PO_{4-P} (mg/l)	1.26 ± 0.3	2.21 ± 0.2	1.98 ± 0.1	1.64 ± 0.1	2.2 ± 0.3	2.9 ± 0.5	2.7 ± 0.5	2.4 ± 0.5
E. coli (cfu)	25.6 ± 3.7	45 ± 4	38 ± 20	33.6 ± 10	28 ± 1	181 ± 11.5	133.3 ± 15.2	131 ± 4
T. Coli (cfu)	90.3 ± 2.5	91.3 ± 4.3	84 ± 2.6	83.6 ± 1.1	77 ± 1.1	466 ± 27	363 ± 15	148 ± 20

Abbreviations: BOD, biological oxygen demand; COD, chemical oxygen demand; COND, conductivity; DO, dissolved oxygen; DS1, downstream 1; DS2, downstream 2; *E. coli, Escherichia coli*; EP, entry point; NH_4, ammonia; NO_3, Nitrate; PO_4, Phosphate; *T. coli*, *Total Coliforms*; TUR, turbidity; UP, upstream site.

Table 4. Physicochemical and bacteriological characteristics of River 2 (Lodoma).

SEASONS	RAINY SEASON				DRY SEASON			
SAMPLING SITES	US	EP	DS1	DS2	US	EP	DS1	DS2
PARAMETERS	MEAN ± SD				MEAN ± SD			
DO (mg/l)	6.5 ± 0.8	5.6 ± 0.3	6.1 ± 0.4	5.7 ± 0.5	5.8 ± 0.1	2.8 ± 0.2	3.4 ± 0.1	4 ± 0.5
BOD (mg/l)	37.3 ± 13	69 ± 20	45 ± 12.5	34 ± 1	46 ± 20.7	356 ± 58	314 ± 56	192 ± 50
COD (mg/l)	85.6 ± 6.6	82 ± 1	66.5 ± 1.5	33 ± 1.5	99 ± 3.5	761 ± 110	435 ± 18	308 ± 18
pH	7.6 ± 0.1	7.2 ± 0.09	7.4 ± 0.4	7.4 ± 0.3	7.2 ± 0.5	4.3 ± 0.3	4.6 ± 0.2	4.9 ± 0.4
TEMP (°C)	20.4 ± 0.7	21.6 ± 0.7	22.6 ± 1.5	22 ± 1	20 ± 0.1	29.9 ± 0.2	26.2 ± 0.7	25.5 ± 1.3
TUR (NTU)	9 ± 0.03	9.2 ± 0.37	5.8 ± 1.1	5.4 ± 1.3	7.4 ± 0.6	98 ± 11	83.5 ± 4.7	81.3 ± 19
COND (µm/cm)	102.6 ± 6.4	122 ± 2.5	106 ± 3.2	100 ± 3.6	110 ± 10	438 ± 98	410 ± 20	392 ± 10.5
TDS (mg/l)	50 ± 5	69.6 ± 5.5	55 ± 1	49.6 ± 1.5	67.3 ± 6.8	1059.6 ± 121	708 ± 71	399 ± 69
NH_{4-N} (mg/l)	3.1 ± 0.77	4.8 ± 0.2	3.9 ± 0.5	3.9 ± 0.8	3.1 ± 0.4	1.8 ± 2	2.1 ± 0.3	1.95 ± 0.4
NO_{3-N} (mg/l)	4.5 ± 0.1	3.5 ± 0.5	3.5 ± 0.7	4.3 ± 0.34	4.7 ± 0.9	4.3 ± 1	3 ± 0.5	4.9 ± 0.9
PO_{4-P} (mg/l)	1.59 ± 0.5	3.2 ± 0.4	2.5 ± 0.2	2.8 ± 0.5	3.2 ± 0.3	3 ± 0.9	2.6 ± 0.5	2.6 ± 0.54
E. coli (cfu)	28 ± 1	46 ± 3.2	34 ± 2	36.1 ± 1	35.8 ± 1	180 ± 12.1	135 ± 12	128 ± 1.2
T. Coli (cfu)	84 ± 3.6	89 ± 5.4	71 ± 1	76.8 ± 1	88 ± 10	453 ± 51	390 ± 10	160 ± 10

Abbreviations: BOD, biological oxygen demand; COD, chemical oxygen demand; COND, conductivity; DO, dissolved oxygen; DS1, downstream 1; DS2, downstream 2; *E. coli, Escherichia coli*; EP, entry point; NH_4, ammonia; NO_3, Nitrate; PO_4, Phosphate; *T. coli, Total Coliforms*; TUR, turbidity; UP, upstream site .

Table 5. Physicochemical and bacteriological characteristics of River 3 (Kedela).

SEASONS	RAINY SEASON				DRY SEASON			
SAMPLING SITES	US	EP	DS1	DS2	US	EP	DS1	DS2
PARAMETERS	MEAN ± SD				MEAN ± SD			
DO (mg/l)	7.7 ± 0.9	6.8 ± 0.3	5.3 ± 1	6.6 ± 0.5	6.1 ± 0.8	2.6 ± 0.2	3.2 ± 0.6	4.6 ± 0.2
BOD (mg/l)	35.66 ± 1.2	66.6 ± 20	44.3 ± 13.5	33.3 ± 1.5	45 ± 1	782 ± 97	395 ± 50	215 ± 15
COD (mg/l)	79 ± 9.5	83 ± 1	63.2 ± 4.5	33 ± 0.2	90 ± 3	1072 ± 183	470 ± 47	322 ± 21
pH	6.6 ± 0.4	6.2 ± 0.23	6.8 ± 0.1	6.7 ± 0.2	5.8 ± 0.7	3.6 ± 0.2	4.5 ± 0.4	5.3 ± 0.3
TEMP (°C)	23 ± 1	24.1 ± 0.7	22.5 ± 1.3	23.4 ± 1.3	22 ± 1	33 ± 1	28 ± 1	25.8 ± 1.8
TUR (NTU)	8.1 ± 2	5.8 ± 2.5	6.7 ± 1.3	8.5 ± 0.95	9.3 ± 0.56	121 ± 8.5	105 ± 6.2	96 ± 8.6
COND (µm/cm)	106 ± 5.7	127 ± 6.4	134 ± 14	116 ± 17	102 ± 10.7	643 ± 56.3	402 ± 16.6	295 ± 5.5
TDS (mg/l)	53 ± 10	70 ± 5.5	55.2 ± 1.3	50.2 ± 0.8	83 ± 1	1361 ± 169	701 ± 116	453 ± 89.5
$NH_{4\text{-}N}$ (mg/l)	3.9 ± 0.6	4.5 ± 2	4.2 ± 1.1	4.2 ± 0.8	3.2 ± 0.5	1.75 ± 0.2	2.2 ± 0.4	2 ± 0.5
$NO_{3\text{-}N}$ (mg/l)	4.4 ± 1	4.1 ± 0.3	3.9 ± 0.6	4 ± 0.5	4.9 ± 0.8	4.5 ± 1.1	3.1 ± 0.6	4.7 ± 1.7
$PO_{4\text{-}P}$ (mg/l)	1.44 ± 0.5	2.1 ± 0.3	2 ± 0.2	2 ± 0.09	2.4 ± 0.4	2.8 ± 0.5	2.9 ± 0.5	2.7 ± 0.6
E. coli (cfu)	75.6 ± 0.6	91 ± 11	73 ± 0.9	72 ± 1.7	76 ± 8.6	213 ± 41	141 ± 10	131 ± 4.1
T. Coli (cfu)	97.9 ± 5.5	94 ± 14	93 ± 13	100 ± 2	78 ± 10	493 ± 66	430 ± 30	191 ± 50

Abbreviations: BOD, biological oxygen demand; COD, chemical oxygen demand; COND, conductivity; DO, dissolved oxygen; DS1, downstream 1; DS2, downstream 2; *E. coli, Escherichia coli*; EP, entry point; NH_4, ammonia; NO_3, Nitrate; PO_4, Phosphate; *T. coli, Total Coliforms*; TUR, turbidity; UP, upstream site.

parameters like DO, pH, and NH_4, were below the standard. The overall river quality indicates spatial and temporal variation in the sites downstream of the coffee processing plant were significantly harmed than the upper stream sections. This was significantly higher at dry season when coffee processing intensifies. This shows that the river was polluted by the effluents directly or indirectly discharged from coffee processing plants. In comparison with the other rivers this river was more polluted than others, this may be due to the fact that this river had more coffee processing plants on its left and right sides which use the river water for pulping and washing the coffee and at the same time discharges the effluents on both side.

Meleya River is also found in Aroresa Woreda. As the results in Table 6 indicated most of the parameters like TDS, BOD, COD were above the limit set by EEPA[12] while parameters like DO, pH, and NH_4 were below the standard. The overall quality of the river indicates that spatial and temporal variation of the sites downstream of the coffee processing plant were significantly harmed than the upper stream parts. This was significantly higher at dry season when coffee processing intensifies and shows that the river was polluted by the effluents directly or indirectly discharged from coffee processing plants.

Conclusions

The level of pollution of the river water was indicated by COD, BOD, DO, pH, TSS, TDS, and electrical conductivity from coffee processing plants. The rivers of the study area were recipient of coffee processing effluent of poor quality that does not meet the permissible limit for surface water quality. The Experimental results indicated that NO_3 and PO_4 were within the range of permissible limit for surface water. Whereas, high values of BOD, COD, TDS, temperature, and conductivity were observed particularly on the entry point and downstream sites (EP and DS) after coffee processing time.

Similarly the rivers water was very acidic and has lower dissolved oxygen which indicates that the rivers had deteriorated quality. The water quality of the selected rivers shows temporal and spatial variation by which as the river crosses the coffee processing plants quality of certain samples reveals that it was getting deteriorated at the downstream. The average concentrations of turbidity, temperature, EC, BOD, COD, and TDS at the downstream sites were higher than the ambient environmental standards, while DO, NH_3, and pH were lower, particularly after coffee processing time. Furthermore, the bacteriological quality of the rivers was indicated by a dense population of indicator bacteria such as total coli form and

Table 6. Physicochemical and bacteriological characteristics of River 4 (Meleya).

SEASONS	RAINY SEASON				DRY SEASON			
SAMPLING SITES	US	EP	DS1	DS2	US	EP	DS1	DS2
PARAMETERS	MEAN ± SD				MEAN ± SD			
DO (mg/l)	7.4 ± 1.1	5.8 ± 0.3	5.7 ± 1.1	5.6 ± 0.4	5.5 ± 0.2	2.4 ± 0.1	2.6 ± 0.2	4.3 ± 0.4
BOD (mg/l)	40.6 ± 14.4	65 ± 4.7	47 ± 8.1	41 ± 7.2	39 ± 13	326 ± 32	264 ± 51	165 ± 5
COD (mg/l)	74.3 ± 14	78 ± 2.5	47 ± 2.5	46 ± 6.8	71.5 ± 21	758 ± 108	412 ± 47	311 ± 53
pH	6.4 ± 0.2	6.5 ± 0.3	6.6 ± 0.1	6.5 ± 0.1	5.4 ± 0.31	4.3 ± 0.2	4.3 ± 0.6	5.3 ± 0.2
TEMP (°C)	22 ± 1.3	22.9 ± 2	23 ± 1.5	22.3 ± 1.5	22 ± 1	31 ± 1.2	29 ± 0.8	26.3 ± 0.6
TUR (NTU)	7.9 ± 1.7	6.6 ± 2.1	6.3 ± 1.5	6.7 ± 1.3	7.9 ± 1.1	92.6 ± 2.7	73 ± 7	85.5 ± 14
COND (µm/cm)	110 ± 9.3	125 ± 4.3	127 ± 23	122 ± 5.5	117 ± 6.8	458 ± 107	343 ± 56.2	282 ± 13.1
TDS (mg/l)	53 ± 1	67.4 ± 1	56.8 ± 2	53.8 ± 1.2	64 ± 7.6	986 ± 11	607.3 ± 10	452 ± 24
$NH_{4\text{-}N}$ (mg/l)	3.2 ± 0.6	4.8 ± 1	3.9 ± 0.5	4 ± 0.82	3.3 ± 0.5	1.9 ± 1.5	2.08 ± 0.4	2.1 ± 0.5
$NO_{3\text{-}N}$ (mg/l)	4.8 ± 0.81	5.4 ± 0.83	4.2 ± 0.58	4.7 ± 0.64	4.8 ± 0.8	4.2 ± 0.9	2.9 ± 0.5	4.8 ± 0.2
$PO_{4\text{-}P}$ (mg/l)	1.6 ± 0.8	2.6 ± 0.4	2.2 ± 0.3	2.4 ± 0.47	2.3 ± 0.56	2.9 ± 0.5	2.6 ± 0.46	2.5 ± 0.54
E. coli (cfu)	77 ± 1	78 ± 16	71 ± 1.3	69 ± 5.2	52 ± 19	188 ± 11	133 ± 15	117 ± 12
T. Coli (cfu)	92 ± 8.1	94 ± 14	93 ± 13	100 ± 2	97 ± 10	453 ± 51	400 ± 45	156 ± 12

Abbreviations: BOD, biological oxygen demand; COD, chemical oxygen demand; COND, conductivity; DO, dissolved oxygen; DS1, downstream 1; DS2, downstream 2; *E. coli, Escherichia coli*; EP, entry point; NH_4, ammonia; NO_3, Nitrate; PO_4, Phosphate; *T. coli, Total Coliforms*; TUR, turbidity; UP, upstream site.

E. coli, which were significantly higher at downstream sites, especially during the dry season, than during the wet season.

In general, this study found that some of the chemical parameters were above EEPA standards. Furthermore, the qualitative analysis revealed that effluent discharges impacted community members, particularly those living downstream of coffee processing plants. The river water they use for various purposes becomes polluted and unfit for drinking, recreation, irrigation, and animal watering. The river becomes colored, odorous and contaminated with suspended materials which make it esthetically deteriorated. In addition to frequent incidences of malarial disease, diarrhea, abdominal pain, children's washing their body suffered with skin irritation. These all biodiversity and health effects were frequently observed after coffee processing time. The development of coffee processing industries in developing countries like Ethiopia is an encouraging phenomenon from economic and social development point of view but industrial wastes should be effectively treated and properly managed. To that end, local and regional governments should work to raise awareness and provide health education to help alleviate the situation. Furthermore, additional research on the detailed physicochemical and bacteriological quality of rivers receiving effluents from wet coffee processing plants should be conducted for the future intervention.

Author Contributions

First authors designed the research methodology and prepared the research proposal. Data collection and organization and the manuscript write-up was done by all authors. Final approval of the manuscript was also done by all authors.

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