SINET: *Ethiop. J. Sci.*, 31(1):69–74, 2008
© Faculty of Science, Addis Ababa University, 2008 ISSN: 0379–2897

Short communication

THE EFFECT OF WET COFFEE PROCESSING ON WATER QUALITY IN STREAMS AND RIVERS OF JIMMA ZONE, SOUTHWESTERN ETHIOPIA

Solomon Endris [1], Worku Legese [2], Tesfu Kebede [1], Behailu W/Senbet [1] Yared Kassahun [1] and Tesfaye Yakob [1]

[1] Ethiopian institute of agricultural research, Jimma Agricultural Research center, PO Box 192, Jimma, Ethiopia. E-mail: solomonendris@yahoo.com
[2] School of Environmental Health, Jimma University, PO Box 820, Jimma, Ethiopia

ABSTRACT: Southwestern Ethiopia is one of the biggest coffee producing regions of the country. The number of coffee processing stations in the region has increased in recent years due to the higher market price for wet processed coffee. However, the risk of environmental pollution has been amplified as a result of the increased wet coffee processing activities. This study was therefore conducted to assess the level of pollution in the streams of the region in relation to wet coffee processing. Water quality of the streams was monitored throughout the study period. The study revealed a high level of organic pollution at locations below coffee effluent discharge points. Physicochemical characterization of water samples indicated that the level of pollution in most of the streams requires very urgent attention. Moreover, the richness of macro-invertebrate community composition was also considered which confirmed existence of a similar pattern of pollution in most of the downstream locations. It is therefore concluded that unless better ways of effluent management and factory water recirculation are strictly in use by wet processing stations in the region, there will be serious repercussions to the environment where rivers and streams become no longer safe as a source of water for household use.

Key words/phrases: Coffee, Ethiopia, macroinvertebrate, water pollution, wet coffee processing

INTRODUCTION

Coffee is produced in many parts of Ethiopia, but based on the ecological requirements of the crop and volume of production, southwestern Ethiopia is the most important region of the country. According to a report by the Central Statistical Authority of Ethiopia (CSA, 2002), an estimated 32145 tons of coffee has been produced in Jimma zone alone in the year 2001/02.

Coffee is processed using either of the two widely known methods: wet and dry processing. When properly done, wet processing of coffee ensures that the intrinsic qualities of the coffee beans are better preserved, producing a green coffee which is homogeneous and has few defective beans. Hence, the coffee produced by this method is usually regarded as being of better quality and commands higher prices. Therefore, the number of wet processing stations in south-western Ethiopia has increased tremendously in recent years, which in turn has resulted in the generation of huge amounts of processing by-products mainly coffee pulp and effluents. A large volume of coffee processing effluent is generated from wet processing stations that are often found scattered along rivers and streams. Coffee processing by-products generated from these wet coffee processing stations are then damped into the nearest river or to nearby places where seepage in to the rivers is highly likely.

A considerable amount of water is required in the wet method of coffee processing. It is estimated that 40 m^3 of water per tone of clean coffee is the required amount for receiving the cherries, transporting them hydraulically in the pulping machine via the water current, removing the pulp, and sorting and repassing any cherries with residual pulp adhering to them (Coste, 1992). Due to such very high demand of water, processing stations are often constructed near permanent water sources.

Despite the higher quality and better price of washed coffee in the international market, the wet method of coffee processing causes environmental problems due to the very high consumption of water and the discharge of effluents with large volumes of organic waste.

The main pollution in coffee wastewater stems from the organic matter set free during pulping, particularly the difficulty to degrade mucilage layer surrounding the beans (Von Enden and

Calvert, 2002). The composition of coffee pulp and mucilage is given below in Table 1. The sugars contained in this mucilage ferment and the organic and acetic acids from the fermentation of the sugars make the wastewater quite acidic, a condition in which higher plants and animals can hardly survive (Von Enden and Calvert, 2002).

In addition to physicochemical properties of water samples, the richness of macroinvertebrate community composition is used in monitoring the water quality of river systems. Based on grouping the macroinvertabrates in order of their tolerance to pollution, various methods have been developed and utilized (Metcalfe, 1989; Noris and Noris, 1995). Macroinvertebrate community changes in relation to water pollution have therefore been well documented in the literature (Hellawell, 1986; Abel, 1989; Mason, 1991; Rosenberg and Resh, 1993 cited in Cao *et al.*, 1997).

Therefore, this study was carried out to assess the level of contamination of rivers and streams in the region as a result of the increasing number of wet coffee processing plants which subsequently increased the amount of coffee processing waste water (effluents) generated and discharged to the surrounding environment.

MATERIALS AND METHODS

Description of the study area

The study was carried out in Jimma zone, 380 km southwest of Addis Ababa in the Oromiya region (Fig. 1). Rivers and streams often used as location factor for coffee washing stations were considered both at upper and lower course and at off and peak processing seasons.

Methodology

a) Physico-chemical characterization

In situ and *ex situ* measurements of pH, temperature (T°), dissolved oxygen (DO), electrical conductivity (EC), ammonia (NH_3), nitrate (NO_3^-), phosphate (PO_4^{3-}), and biological oxygen demand (BOD) were done.

b) Macroinvertabrates sampling

Macroinvertebrates were sampled following a standard procedure, Kick sample over a period of three minutes, using 153-µm Wagtech field-master plankton net. Up to four individual samples were composited into a single sample for taxonomic identification. Samples were preserved using 70% alcohol prior to sorting and identification. In case of collecting samples below the outfall of coffee waste discharge points, the sites were placed at 100 meters downstream to allow sufficient dispersion of effluent into the river.

During the study, identification of all macroinvertabrates in each specimen has been carried out. However, only three orders namely ephemeroptera, plecoptera, and trichoptera, which are all grouped under pollution sensitive taxa (Reif, 2002), are used in this paper. Finally, the bio-monitoring index - EPT richness, was used to evaluate the level of pollution of rivers and streams in the area.

Table 1. Chemical composition of coffee pulp and mucilage.

Composition of coffee pulp (Clifford and Willson, 1985)		Composition of mucilage (Gathua *et al.*, 1991)	
Contents	Proportion (%)	Contents	Proportion (%)
Ether extract	0.48	Water	84.20
Crude fiber	21.4	Protein	8.00
Crude protein	10.1	Sugars	
Ash	1.5	Glucose (reducing)	2.50
Nitrogen free extract	31.3	Sucrose (non- reducing)	1.60
Tannins	7.8	Pectin	1.00
Pectic substances	6.5	Ash	0.7
Non reducing sugars	2.0		
Reducing sugars	12.4		
Chlorogenic acids	2.6		
Caffeine	2.3		
Total caffeic acid	1.6		

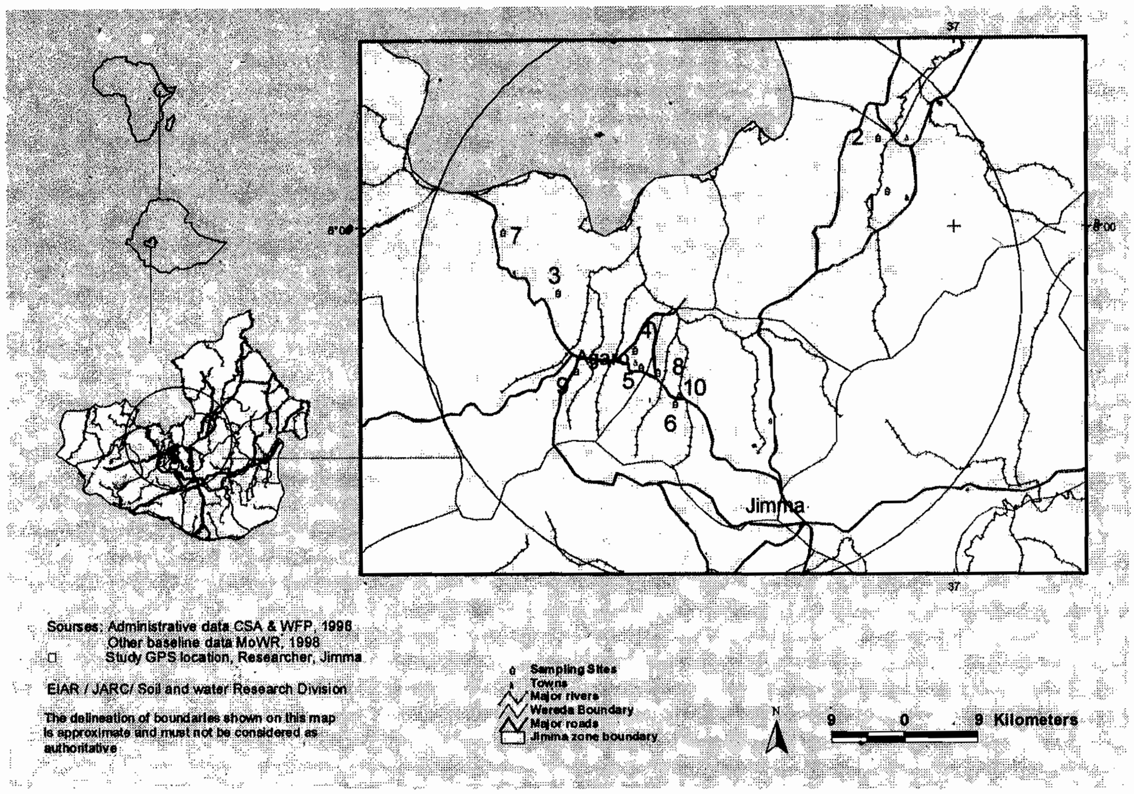

Fig. 1. Map showing study sites in the coffee processing areas of Jimma zone.

RESULTS AND DISCUSSION

The physicochemical characteristics of water samples collected from the different streams in the study site are given in Table 2. Macroinvertebrates were also collected and EPT richness data presented in Table 3.

The data collected indicated deterioration of water quality as a result of coffee processing effluent in most of the streams sampled. Dissolved oxygen (DO) values as low as zero were recorded in some of the streams (Table 2). The decrease in oxygen content is the main ecological effect of organic pollution in a water course into which effluents have been discharged (Murthy *et al.*, 2005). The organic substances diluted in the wastewater breakdown very slowly by microbial process, using up oxygen from the water. Due to the decrease in dissolved oxygen content, the demand for oxygen to break down organic material in the wastewater exceeds the supply, thus creating anaerobic conditions (Von Enden and Calvert, 2002).

Most of the pits in the study area that were intended to serve as wastewater stabilization are neither properly constructed nor in the right dimension to accommodate the generated waste during peak processing time leading to overflow of raw effluents into the natural water course. This is a considerable deviation from the line of modern thinking where the development of solutions for pollution is best effected with the concept of waste minimization followed by treatment. As a result the polluting potential of the factories is enormous as shown by the BOD content of coffee effluents reaching up to 1600 mg/l even after stabilization in a pit (Table 2). Values for biological oxygen demand (BOD), indicating the amount of oxygen needed to break down organic matter in waste water, were as high as 1200 and 1600mg/L in streams like Bore and Temssa, respectively (Table 2).

However, samples from upstream locations of the same streams had BOD values of 2.6 and 3.15 mg/L respectively (Table 2), indicating deterioration of water quality in downstream locations where coffee effluent is seeped in to the water course. BOD greater than 10 mg/l usually indicates the presence of gross pollution (Nathanson, 2000). Many rivers in this study show values approaching or exceeding this limit during the wet coffee processing season. A corresponding decline in abundance and diversity of EPT taxa has been noted in many rivers receiving wastewater from coffee processing factories (Table 3).

Table 2. Physico-chemical characteristics of water samples from rivers of Jimma zone at locations above and below coffee effluent discharge points.

Sampling sites	DO		pH		T° (°C)		EC (µS/m)		NH_3		NO_3^-		PO_4^{3-}		BOD	
	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L
Dembi	7.42	6.78	7.41	5.56	19.9	21	60	90	0.122	0.54	0.23	0.14	0.28	0.12	2.1	42
Wurssa	5.74	1.88	7.00	5.56	18.4	17.3	110	240	0.7	17.4	0.48	N.A	0.16	0.24	4.1	366
Dengaja	6.6	7.68	6.92	7.34	17.8	18.5	70	80	0	1.45	0.28	N.A.	0.19	0.18	2	13.3
Sunde	6.85	4.89	7.38	7.00	21.5	19.5	70	80	0	1.8	0.2	N.A.	0.54	0.1	2	16
Kolombo	7.02	6.24	7.35	7.18	15.3	19	70	90	0.34	1.2	0.4	0.28	0.19	0.38	5.2	5
Torbaho	7.13	5.11	7.61	7.14	19.2	N.A.	70	160	1.24	0.099	0.24	0.83	0.42	0.098	1.2	68
Bore	7.97	2.85	7.25	4.88	16.7	18.4	70	630	10.73	21.36	0.32	17.8	0.18	7.04	2.6	1200
Wanja	6.19	5.67	7.44	7.57	N.A.	18.8	80	90	0.342	0.25	1.2	N.A.	0.342	0.08	1	20
Temssa	7.41	0	5.95	4.3	18.8	23.8	100	800	0	19.8	0.32	17.2	0.29	9.9	3.15	1600
Urgessa	7.45	5.79	6.27	2.1	22.2	19.8	70	320	0	16.3	Trace	12	0.23	2.2	3.2	480
Average	6.98	4.69	7.06	5.86	18.87	19.57	77	258	1.35	8.02	0.41	8.04	0.28	2.03	2.66	381.03

Note: U, sampling points above effluent discharge; L, sampling points below effluent discharge. All units except temperature, pH and EC are in mg/l.

Concentration of NH_3, NO_3^-, NO_2^- and PO_4^{3-} in most of the streams surveyed were comparatively high at downstream locations than upper course of the same streams (Table 2).

The lowest ammonia concentration was zero at upper locations and the highest was at the lower course of Temsa River with a concentration of 19.8mg/L. The mean NH_3 concentration was 1.35 mg/L and 8.02 mg/L at the upstream and downstream locations respectively. Similarly, nitrate concentration increased following effluent discharge (Table 2). Trace amounts of NO_3^-were found at upper course of most rivers, while as high as 17.2 mg/L and 17.8mg/L were recorded at downstream locations of Temsa and Bore Rivers. The average NO_3^- concentration in water samples from locations above coffee effluent discharge points was 0.41 mg/L while in locations below effluent discharge points it averaged 8.04 mg/L (Table 2). Phosphate concentration also increased with the discharge of coffee effluent in all rivers (Table 2).

It was also found that the lower course of rivers like Bore, Temssa a nd Urgessa was very acidic. The lowest pH level recorded (2.1) was at Bore hence indicating the active decomposition of organic matter. As the organic wastes oxidize, CO_2 is released and increase the acidic characteristics of the water decreasing the pH value below the range of 6.5-8.5; which is WHO standard for any source of water for human use (WHO, 1986).

During the study, identification of all macro-invertabrates in each specimen has been carried out. However, only three orders namely ephemeroptera, plecoptera, and tricoptera, which are known to be highly sensitive to pollution (Reif, 2002), are used in this paper. This is because water quality indices based on macroinvertebrates should be robust and yet sensitive enough to separate out the effects of pollution from natural variations. Thus, indices that are not unduly influenced by natural variations such as flood disturbances and seasonal changes are better tools for water pollution monitoring. To this end, the EPT taxa are not only the most sensitive to pollution but also the most robust in separating out natural disturbances from anthropogenic impact of rivers and streams (Karr and Chu, 1999).

Orders of Ephemeroptera, Plecoptera and Tricoptera are known to be good indicators of organic pollution for they are sensitive to the oxygen budget of a given water body. As can be observed from the upstream and downstream distribution of macroinvertebrates, it is evident that generally these three orders decline in abundance and diversity downstream relative to upstream sites (Table 3). This supports the accepted view that sensitive species are reduced when water quality deteriorates (Reif, 2002).

Macroinvertebrates are sensitive to different chemical and physical conditions. If there is a change in the water quality, perhaps because of a pollutant entering the water, or a change in the flow downstream of a river, then the macro-invertebrate community may also change (Water Facts, 2001). Therefore, the richness of macro-invertebrate community composition in a water body can be used to estimate the level of pollution or contamination of rivers in the region.

Table 3. EPT **Taxa richness at locations above and below coffee effluent discharge points in different rivers of Jimma zone.**

No.	Sampling sites (Rivers)	Ephemeroptera		Plecoptera		Trichoptera	
		Upper course	Lower course	Upper course	Lower course	Upper course	Lower course
1	Dembi	79	-	15	-	1	-
2	Wurssa	2	2	-	-	-	-
3	Sunde	81	3	28	-	-	-
4	Dogaja	61	14	-	6	-	-
5	Kolombo	35	31	18	-	1	-
6	Torbaho	74	-	4	-	-	-
7	Bore	-	-	-	-	-	-
8	Wanja	29	44	14	-	1	-
9	Temssa	-	-	-	-	-	-
10	Urgessa	125	-	2	-	-	

The combination of high acidity, and high BOD, depleting life-supporting oxygen from the water, is causing serious problems affecting the ecological integrity of river systems in Jimma zone. This condition therefore entails an immediate intervention in the areas of coffee factory water recirculation and other effluent management options.

CONCLUSION

Result of the physicochemical characterization and biological monitoring of streams in the region (Jimma zone, Southwestern Ethiopia) stressed the need for a sound effluent treatment or management option in order to ensure sustainability of coffee production and avoid environmental pollution. Disposal of coffee processing effluent and other by-products (mainly coffee pulp) caused water quality deterioration which was clearly demonstrated by the combination of high acidity, high BOD, low DO and low EPT richness in downstream locations of the streams monitored during the study. Hence, wet coffee processing negatively affected the ecological integrity of river systems in the region where most of the streams are rendered unusable for the local people, especially during the processing season.

Therefore, this condition entails an immediate intervention in the areas of coffee factory water recirculation and other efficient and cheap effluent management options. As outlined by researchers working on the issue of coffee wastewater management, the development of solutions for pollution reduction is best effected by the concept of waste minimization followed by treatment, rather than the alleviation of the present problems by treatment alone (Mburu, 2001, 2004; Chanakya and De Alwis, 2004). Many approaches have been tested in different coffee producing countries to get the pollution load under control. Anaerobic settling ponds, artificial aeration, biogas reactors, land application by irrigation or wetlands, using seepage pits or trenches (seepage of effluent through the soil before it reaches the river), and utilizing water efficient pulper devices are among the most commonly practiced options in countries where there is intensive wet coffee processing.

ACKNOWLEDGEMENTS

The financial support from the EU-funded coffee improvement project (CIP-IV) of Jimma Agricultural Research Centre is strongly acknowledged. We also appreciate the contribution and collaborative effort by Jimma University (School of environmental Health). Lastly, the contribution of Ato Abrar Sualeh and Ato Daniel Sahle during the field work is duly acknowledged.

REFERENCE

1. Cao, Y., Bark, A.W., Williams, W.P. (1997). Analyzing benthic macroinvertebrate community changes along a pollution gradient: a framework for the development of biotic indices. *Wat. Res.* 31, 4:884–892.

2. Chanakya, H.N. and De Alwis, A.A.P. (2004). Environmental issues and management in primary coffee processing, *Process Safety and Environmental Protection*, 82(B4):1–10.

3. Clifford, M.N. and Willson, K.C.W. (eds) (1985). *Coffee Botany, Biochemistry and Production of Beans and Beverages*. Croom Helm, England, pp. 234-243.

4. Coste, R. (1992). *Coffee: the Plant and the Product*. Macmillan Press Limited, London.

5. CSA (2002). Statistical Abstracts, Central Statistical Authority. Addis Ababa, Ethiopian Authority for Finance and Economic Development.

6. Gathua, B., Rantala, P. and Maatta, R. (1991). Coffee industry wastes. *Water Science Technology*, Vol. **24**(1):53-60.

7. Karr, J.R. and Chu, E.W. (1999). *Restoring Life in Running Waters. Island* Press, Covelo, California.

8. Mburu, J.K. (2001). The environmental considerations featuring in the processing of coffee in Kenya. **In**: *The 19th International Conference on Coffee Science*, ASIC, May 14 to 18, 2001, Trieste, Italy.

9. Mburu, J.K. (2004). Coffee processing waste management. **In**: *The 20th International Conference on Coffee Science*, ASIC, October 11 to 15, 2004, pp. 513-516, Bangalore, India.

10. Metcalfe, J.L. (1989). Biological water quality assessment of running water based on macroinvertebrate communities: history and present status in Europe. *Environ. Pollut.* 60:101-139.

11. Murthy, K.V.N., Antonette, D. and Gaurav, K. (2005). An effluent treatment-cum-electricity generation option at coffee estates: is it financially feasible? Draft document, International Energy Initiative, Bangalore, India (http://www.iei-asia.org) (Accessed on December 22, 2005).

12. Nathanson, J.A. (2000). *Basic Environmental Technology: Water Supply, Waste Management and Pollution Control*, 3rd ed. Prentice-Hall Inc., Upper Saddle River, New Jersey.

13. N oris, R.H. and Noris, K.R.. (1995). The need for biological assessment of water quality: Australian perspective. *Aust. J. Ecol.* **20**:1-6.

14. Reif, A.G. (2002). Assesment of stream quality using biological indices at selected sites in the Delaware River Basin, Chester County, Pennsylvania, 1981-1997: U.S. Geological Survey Fact Sheet FS -116-02. (http://www.-chesco.org/water/index.html) (Accessed on December 22, 2006).

15. Von Enden, J.C. and Calvert, K.C. (2002). Limit environmental damage by basic knowledge of coffee wastewaters. GTZ - PPP Project "Improvement of coffee quality and sustainability of coffee production in Vietnam".

16. Water facts: water and rivers commission, October 2001 (2nd edition). (http://www.wrc.wa.-gov.au/ribbons) (Accessed on January 25, 2006).

17. WHO (1986). WHO Handbook, Geneva, Switzerland.