An effluent treatment-cum-electricity generation option at coffee estates: is it financially feasible?

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Abstract

This paper discusses the environmental effects of the effluents discharged from coffee processing units and the feasibility of an effluent treatment process involving a bioreactor. The benefits from using such a method for wastewater treatment include: reduction in pollution of the surrounding area, recycling of water, and production of biogas that can be used with diesel to fuel a dual-fuel generator. A study of the feasibility of investment in this effluent treatment process is therefore warranted, particularly because of the importance of coffee production in South India. At present, penalties for effluent discharge have not been levied and the charges for water supply are low, hence financial returns on the bioreactor investment are obtained only through the avoided cost of the amount of diesel replaced by biogas. The estimates obtained from the case study indicate that this effluent treatment process is financially viable. If environmental policies were more stringent, this effluent treatment-cum-electricity generation option would be even more attractive.

Background

Currently ranked sixth in the world in coffee production, India grows about 3 lakh tonnes annually (Table 1). Coffee is also an export earner, with 80 per cent of the production exported at a value of Rs 1,703 crores (US$ 3.62 million[1]) in 2000-01[2]. Karnataka is India's largest coffee-producing state, contributing about 69.4% per cent of the total (Table 2).

Table 1: Coffee -- Variety-wise Area & Production in India (2000-2001)

Variety	Area		Production	
	in hectares	% of total	in tonnes	% of total
Arabica	167,792	48.1	121,050	40.2
Robusta	181,203	51.9	179,550	59.8
Total	348,995		300,600	

Source: India Coffee Board, 2003.

Table 2: Coffee -- State-wise Area and Production (2000-2001)

State	Area		Production	
	in hectares	% of total	in tonnes	% of total
Karnataka	201,775	57.8	208,670	69.4
Kerala	84,795	24.3	66,690	22.2
Tamil Nadu	30,681	8.8	21,630	7.2
Others	31,744	9.1	3,610	1.2
Total (All-India)	**348,995**	**100.0**	**300,600**	**100.0**

Source: India Coffee Board, 2003.

Most Indian coffee farms are categorised as small to medium sized (less than 15 hectares). The current intensive coffee production in India is characterised by specific husbandry techniques such as high-density planting, pruning, intensive use of fertilisers and pesticides, and replanting with high-yielding drought- and disease-resistant varieties.

Coffee processing

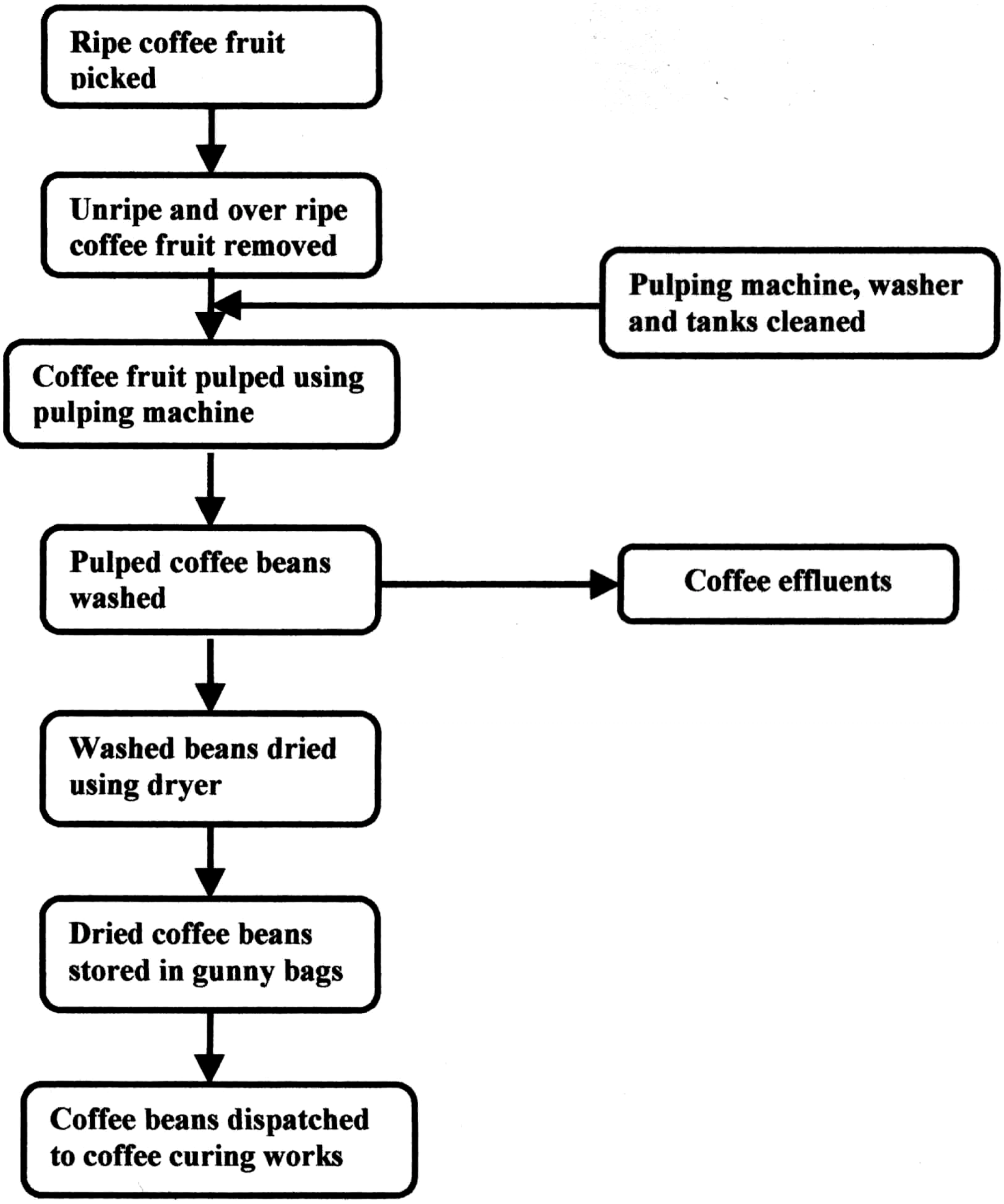
Attracted by the export potential, many large coffee growers have invested in coffee-processing equipment. The intensive production and processing methods have resulted in higher yields but, on the other hand, have had their impact on the environment, as will be discussed.

Coffee is processed either by the wet method to produce 'plantation / parchment coffee' or by the dry method to obtain 'cherry coffee'. In India, it is primarily the wet method that is used to process freshly picked coffee fruit.

Figure 1 gives a schematic representation of the wet method of coffee processing. Selection of ripe coffee fruit is essential for producing good quality coffee beans. The fruit is soaked overnight in water and then pulped using pulping machines. The coffee beans obtained are then washed, and the skin and other refuse (mucilage) removed mechanically. The washed beans are then dried using suitable drying platforms. The wastewater[3] from the pulping machines and washers also contains coffee effluents that need to be treated before discharge. The dried coffee beans are stored in gunny bags, preferably kept on wooden planks to avoid dampness, till they are dispatched to the coffee curing works.

The effluents from the process containing matter in suspension, as well as organic and inorganic compounds in solution, have to be suitably discharged. These can be basically divided into two parts: the wastewater from the pulping process, with a high content of fermenting sugars, and the thick effluents from the mechanical mucilage removers.

Figure 1: Schematic representation of "wet" coffee processing



Environmental issues

The coffee curing process has been causing environmental problems at the local level not only due to the consumption of water and firewood, but more due to the discharge of effluents with large volumes of organic waste.

Pollutants in coffee wastewater emerge from the organic matter set free during pulping, especially due to the difficulty in degrading the mucilage layer surrounding the beans. Tables 3 and 4 give the composition of coffee pulp and the mucilage, respectively. The sugars contained in this mucilage ferment. The organic and acetic acids from the fermentation of the sugars make the wastewater very acidic (with pH as low as 3.8), a condition in which higher plants and animals can hardly survive. Moreover, the total suspended solids in the effluents are high; in particular, the digested mucilage, when precipitated out of the solution, builds a crust on the surface, clogging up waterways and further contributing to the anaerobic conditions.

Table 3: Composition of coffee pulp

Contents	**Proportion (%)**
Ether extract	0.48
Crude fibre	21.40
Crude protein	10.10
Ash	1.50
Nitrogen free extract	31.30
Tannins	7.80
Pectic substances	6.50
Non reducing sugars	2.00
Reducing sugars	12.40
Chlorogenic acid	2.60
Caffeine	2.30
Total caffeic acid	1.60

Source: GTZ-PPP, 2002

Table 4: Composition of mucilage

Contents	**Proportion (%)**
Water	84.20
Protein	8.00
Sugars - Glucose (reduction) - Sucrose (non reducing)	 2.50 1.60
Pectin	1.00
Ash	0.70

Source: GTZ-PPP, 2002

In addition, the presence of some toxic chemicals – alkaloids, tannins, and polyphenolics -- makes the environment for biological degradation of organic material in the wastewater more difficult.

The main ecological effect of organic pollution in a watercourse (into which effluents have been discharged) is the decrease in oxygen content. The organic substances diluted in the wastewater break down 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. The amount of oxygen needed to biologically break down organic wastes diluted in water, that is, the biological oxygen demand (BOD) could be as high as 15,000 mg/l, while the amount of dissolved oxygen required to combine with chemicals in the wastewater, that is, the chemical oxygen demand (COD),[4] could be between 15,000 and 25,000 mg/l. The resulting anaerobic conditions can be fatal to aquatic creatures and also cause bad odour; moreover, the bacteria cause health problems if the wastewater seeps into a source of potable water.

A sample study of five coffee estates in Karnataka has revealed alarming levels of pollution (as indicated in Table 5). It has been found in studies in other parts of the world too that coffee wastewater has high pollutant potential (for example, de Matos, *et al*., 2001). Thus, the high acidity and depleted life supporting oxygen from the water are major concerns for coffee wastewater treatment.

Table 5: Effluent characteristics as analysed from the 5-coffee estates of Karnataka

	pH value	BOD (mg/l) (5 days at 20°C)	COD (mg/l)	Total solids (mg/l)	Phosphorus (mg/l)	Nitrogen (mg/l)	Type of coffee
Estate A	3.94	15,200	27,840	13,360	5.0	123.3	Arabica
Estate B	4.22	3,600	6,240	5,440	6.8	95.57	Arabica
Estate C	4.13	15,000	31,520	12,876	8.8	0.0	Arabica
Estate D	4.12	10,800	15,040	6,320	4.0	40.32	Robusta
Estate E	4.61	13,200	18,080	11,960	7.3	22.4	Robusta

Source: Adichunchanagiri Institute of Technology, Chikkamagalur, 2002, -- project sponsored by Indian Coffee Board

Another environmental problem is the high requirement of water for coffee processing; as much as 15,000 litres per tonne of cherries (coffee fruit) can be used, if there is no recycling and reuse.

Possibilities for clean coffee effluents

Efforts have been made in various parts of the world to develop an efficient and economic process for treating the wastewater from wet coffee processing. The first recorded effort to treat such wastewater was made in Kenya in the 1950s'. The East African Industrial Research Organisation (EAIRO) worked on it in Uganda in the early 1960s' while IDRC, Canada sponsored research projects in South America in the 1970s'. The first attempt to separate the solids and concentrate on the wastewater cleanup was made in Costa Rica during the 1980s'. However, it did not succeed in handling the mucilage problems and proved to be costly on a large scale (Calvert, 1997). In Papua New Guinea, an UASB (Upflow Anaerobic Sludge Blanket) reactor was used for treating coffee wastewater, along with a biological filter system. In spite of this, the flavonoid colour compounds in coffee skins continued to discolour the rivers and other discharge areas (Calvert, 1997).

The Central Pollution Control Board (CPCB) of India has suggested a technical solution based on the National Environmental Engineering Research Institute (NEERI) design for treatment of coffee effluents. The CPCB option consists of three phases: a neutralisation phase in which the acidic effluent is neutralised with lime, followed by an anaerobic digestion (in a lagoon) and finally an aerobic phase. The main purpose of this effluent treatment scheme is to meet the Board's specification regarding the biological oxygen demand (BOD) and chemical oxygen demand (COD) of the effluents discharged by the processing units into the surrounding areas.

Installing a biogas-reactor or bioreactor is an alternative option for the anaerobic phase of the effluent treatment. The Centre for the Application of Science and Technology to Rural Areas (ASTRA) of the Indian Institute of Science, Bangalore, has developed such a technology. This technology has been implemented at 5 coffee estates in Karnataka state, as a pilot endeavour under the Indo-Norwegian Environmental Project (INEP)[5], commissioned by the Karnataka State Council for Science and Technology (KSCST). The bioreactor not only reduces the BOD and COD levels of the effluents, but releases biogas that can be used for the generation of electricity through a dual-fuel engine.

Figure 2: Schematic representation of the bioreactor

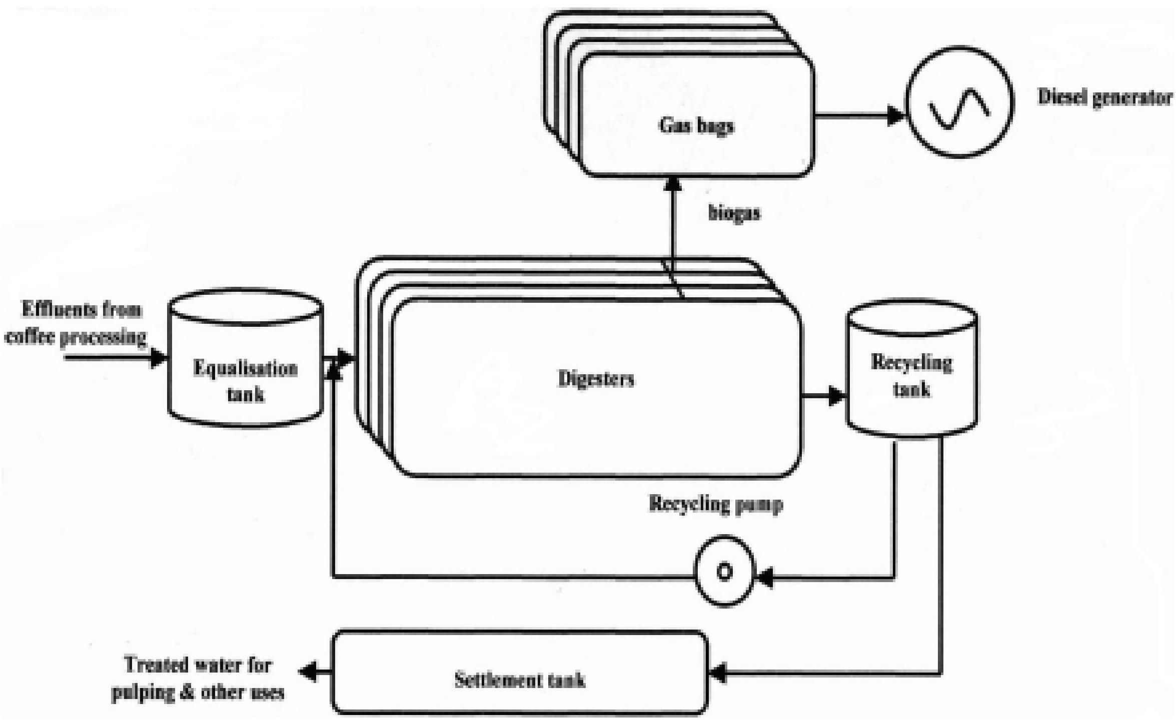


Figure 2 indicates the stages in the effluent treatment process through which effluents from coffee processing are "cleaned" and biogas generated. The three main components of the bioreactor are the equalisation tank, digester and recycling tank. The effluents from the coffee processing unit (with high BOD/COD levels) are initially dosed with commercial lime in the equalisation tank. The purpose of this is to reduce their acidity, in other words, to increase their pH value to the range of 6.5 to 7.5. The pH-corrected effluent then flows to the digester[6]. Two months prior to the pulping season, fresh cow dung and leafy biomass are fed to the digester, to initiate the anaerobic digestion process. As a result of the anaerobic digestion, biogas (a mixture of CH_4 and CO_2 in a ratio 3:2) is released. The gas is stored in gasbags for further use, -- in this case, for the generation of electricity, using a duel-fuel engine. The treated water from the digester is collected in a recycling tank for re-circulating to the digester for at least 2-3 hours a day to obtain further reduction in BOD/COD levels. When reusable, the treated water can be used for the pulping section of the coffee processing and for other non-potable uses.

As the bioreactor can handle a high concentration of effluents, the quantity of water used per ton of coffee can be reduced to less than 3,000 litres per ton of coffee berries processed. This also reduces the size of the bioreactor.

In spite of the obvious environmental benefits, the financial viability of investment in this method of coffee wastewater treatment is important as far as the coffee processing units are concerned. Hence a cost-benefit analysis has been carried out.

Case Study

A coffee estate in Chikkamagalur district (one of the main coffee-growing regions of Karnataka) was selected for the purpose of assessing the feasibility of such a project[7]. This estate produces about 1,200 tons of coffee beans annually. Since ground water is difficult to obtain, the estate has to depend to a great extent for its processing requirement of water on the rainwater accumulated in small lagoons. At times, processing has had to be reduced due to the scarcity of water.

Coffee processing, as indicated in the earlier section, results in effluent wastewater (i.e. coffee pulp mixed with water) to the extent of 3,000 litres per tonne of coffee processed. This effluent, when tested by the Karnataka State Pollution Control Board, had a BOD of 10,000 mg/litre, while the acceptable BOD for irrigation/discharge purposes is100 mg/litre.

Construction costs

As already described, the three main components of the bioreactor are the equalisation tank, digester and recycling tank. Table 6 indicates the dimensions required for handling about 8 tonnes of coffee fruit a day. The modular digester consists of four modules in which the effluents are digested to release biogas. Each module is suitable for about 6,000 litres of effluents (from the processing of 2 tonnes of coffee), so that a total of about 24,000 litres per day (from 8 tonnes of coffee fruit) can be dealt with. This can result in gas generation of 80 m^3 per day with a BOD destruction factor of 85%[8].

Table 6: Bioreactor components

Component	length	width	depth
Equalisation tank	3 m	2 m	1 m
Digester modules (x 4)	7 m	4 m	3 m*
Recycling tank	2 m	2 m	1 m

* This depth (or height) of the module excludes the vault (covering).

The total costs of constructing the bioreactor are estimated to be Rs 3.86 lakhs, as shown in Table 7. These are chiefly for the civil construction – material, labour, and supervision. In particular, the reinforced concrete digester vault requires skilled labour not usually available locally. The purchase costs of diesel engine-gensets have not been included, as they are already available at the estate.

Table 7: Construction costs of the bioreactor (in the year 2002)

Component	Costs (Rs)
Civil construction material	1,50,400
Civil labour costs	1,21,100
PVC & GI piping	18,750
Gasbag	12,000
Resin	7,000
Supervision and other expenses	33,000
Other contingencies	43,600
Total	3,85,850

Operating costs

Coffee pulping takes place for approximately 5 months in a year, hence the operation of the bioreactor is being considered for those 150 days. Table 8 lists the operating costs for the season. To start the reactor at the beginning of each pulping season, fresh cow dung of 1,800 kg and 180 m^3 of green leafy biomass are required. If this biomass is not available on the estate, it would have to be purchased, hence the costs of procuring these are included in the annual operating costs. Commercial lime is required for neutralising the acidity of the effluents in the equaliser, at the rate of 1 gm per litre of effluent. Labour charges of one person, for the operation of the biogas unit during the season, must also be included. Diesel engine-gensets are already being operated on the estate, hence the running costs of these do not have to be added. On the contrary, as will be shown, the fuel costs will be reduced to the extent of the replacement of diesel by biogas.

Table 8: Operation costs of the bioreactor (@ 2003 market rates)

Details	Cost (Rs)
Dung (@ Rs 2/kg)	3,600
Lime (@ Rs 3.75/kg)	11,250
Labour cost (@Rs 1,500/month)	7,500
Total annual costs	22,350

Benefits

It would not be financially feasible for coffee processing units to install bioreactors unless the pecuniary benefits exceeded the construction and operation costs. The benefits are: “cleaner” effluents for discharge/disposal, reduced water requirement through recycling and re-use of water, and the production of biogas that can be used in dual-fuel generators. However, these benefits must be financially quantifiable.

Regarding the discharging of effluents, the State Pollution Control Boards specify the tolerance limits. Karnataka State Pollution Control Board’s standards under its Water (Prevention & Control of Pollution) Act, 1974, are listed in Annexe 1. The Tamil Nadu Pollution Control Board (TNPCB) through its Water (Prevention & Control of Pollution) Act, 1978, mandates that all coffee plantations that employ wet method processing or coffee curing should have effluent treatment plants. In 2003, TNPCB has sent notices to several coffee plantations regarding the setting up of effluent treatment plants that meet the standards fixed for the parameters stipulated in the Act (Down to Earth, 2003). However, since there are currently no penalties being imposed for non-compliance, our study is *not* assuming any “avoided cost” of pollution (to compensate for the costs of the proposed effluent treatment).

As indicated in Figure 2, the effluent treatment process involves re-cycling of excess water from the digesters, enabling re-use. If the costs of water delivery were to be estimated, particularly for hilly coffee-growing regions where groundwater is difficult to access and rainwater has to be collected, it would be considerable. However, thus far, the prices/charges imposed for industrial use of water have been very low. Coffee processing is not among the industrial processing units listed in the Water (Prevention and Control of Pollution) Cess (Amendment) Act (MoEF, 2003), but even with the recent doubling of the cess (from 5 paise to 10 paise per kilolitre for some industrial uses like cooling and spraying in mine pits and from 15 paise to 30 paise/kilolitre for processing leading to toxic or not-easily-biodegradable pollutants) [9], water costs remain a negligible proportion of the total processing costs. In this situation, our study has not imputed a value to the benefits of water recycling and re-use.

Hence, the only financially quantifiable benefit is the replacement of diesel with biogas in a dual-fuel engine. The estimation of the avoided cost of diesel is shown in Table 9. Based on the availability of biogas from the processing of 8 tonnes of coffee fruit per day, the total gas generation possible during the 5-month season would be about 12,000 m^3. Used at 0.918 m^3 per kWh, biogas has been shown to replace 77% of the diesel required for the generation of electricity (IEI, 2003). Therefore, the biogas available during the season would enable about 13,072 kWh of electricity to be generated through a dual-fuel engine. The diesel replaceable by biogas, for the generation of this electricity, at 77% of the average use of 0.381 litre/kWh[10], would amount to about 3,830 litres. This represents an avoided cost of Rs 84,300, at current market prices.

Table 9: Calculation of avoided costs (for the estate being studied)

Item	**unit**	**value**
Gas available per day[a]	m^3	80
=> Total gas production during the pulping season (150 days), assumed available for use	m^3	12,000
Biogas required for generating electricity in dual-fuel mode[b]	m^3 per kWh	0.918
=> Electricity generation possible during the season	kWh	13,072
Diesel required for generating electricity in single-fuel mode	litre/kWh	0.381
Diesel required along with biogas in dual-fuel mode[c]	litre/kWh	0.088
=> Diesel saving possible during the season	litres	3,832
Current price of diesel	Rs/litre	22.00
=> Avoided costs of diesel	Rs	84,312

Please note that the five-month long pulping season represents the operational period for the year, so that the costs and benefits for this period can be taken to be annual costs and benefits, respectively.
The sources of information include:
a: H.N.Chanakya, personal communication
b,c: IEI, 2003.

Economic analysis

From the benefits that have been quantified so far, one can estimate financial indicators based on projected cash flows, as well as the annualised costs and benefits, based on discounted cash flow techniques.

Cash flows have been projected for a period of 10 years,[11] assuming an inflation factor of 10% per annum. On the basis of these flows, the *payback period*, that is, the length of time taken to recover the initial cost with net annual returns, is 5.08 years. However, this indicator does not give any weight to the timing of the various cash flows and merely indicates that point when the simple sum of all returns (inflows) obtained just equals the initial cost (outflow).

However, if one weighted the expected flows on the basis of their incidence, then the sooner the costs or benefits occurred in the future, the more they would be worth today, than similar amounts at a later date. The present value (PV) of an amount A, received or paid k years (periods) after the year (period) of reckoning, at an interest (or discount) of i % per year (period), is equivalent to $[A/(1+i)^k]$. Evaluating the expected inflows and outflows in this manner, one can obtain the *internal rate of* *return* (IRR), or that derived rate of interest at which the present value of outflows just equals the present value of expected inflows. For this case, the IRR is 18.3%. This is an acceptable rate as compared to the prevailing interest rates.

Similarly, using the present value of each flow, the *net present value* (NPV), or the present value of the expected *net inflows* (outflows minus inflows), over a 10-year period ranges from Rs 873,486 to Rs 510,827, corresponding to annual interest rates of 2% to 12%. The higher the interest rate i, the larger the denominator $(1+i)^k$ of the PV, and therefore, the lower the present value of future earnings.

The indicators point to this option being financially viable, even without imputing a value for the "cleaning" of the effluents and the water conserved.

Table 10: Financial indicators of the project

Pay back period	years	5.08
Internal rate of return (IRR)	%	18.3
Net Present Value of the cash flows @ 10%	Rs	5,63,290

Apart from the above financial indicators, one can compare the *annualised life-cycle costs and benefits*, that is, the annual values of actual costs and benefits expected to accrue over the working life[12] of the project. The annual benefits have already been estimated (Table 9). The corresponding annual costs include the annualised value of the initial capital costs and the already computed annual operating costs (Table 8). To "annualise" the initial costs, that is, to spread the initial cost over the working life of the project, the annuity factor $[\ i \div \{1 - (1+i)^{-n}\}]$ is used, where i is the rate of interest per year (or period) and n is the total number of years (or periods) of working life. Multiplying this annuity factor by a one-time receipt or payment yields its annualised equivalent. The interest rate chosen can be nominal or "real" (i.e., corrected for inflation), and the computation can be reiterated at several rates of interest, so that one can also determine the interest rate niche within which a project would be most acceptable.

For this case, the civil construction component of the capital costs is expected to have a working life of at least 25 years, while the other capital costs are expected to be re-incurred after 12.5 years. The "annualised" costs are shown in Table 11, at interest rates ranging from 2% to 12%. When these annualised capital costs are added to the operating costs, the total annual costs are obtained.

In contrast, the benefits, i.e., the avoided costs of diesel, even without any assumed inflation, are considerably higher. The benefit-cost ratio extends from more than double, at an interest rate of 1%, to about 1.16, at 12% interest. Only if the applicable interest rate crossed 15.4% would the annualised costs exceed the corresponding annual benefits. As such, the investment is proved economically viable, even on the basis of an annualised cost-benefit analysis.

Table 11: Annualised costs versus annual returns (at a range of discount rates)

		Discount rate per year					
		2%	**4%**	**6%**	**8%**	**10%**	**12%**
Capital costs:							
Civil construction	Rs 348,100						
Working life	25 years						
=> Annuity factor		0.051	0.064	0.078	0.094	0.110	0.127
=> **Annualised civil construction costs**	Rs	17,830	22,283	27,231	32,610	38,350	44,383
Additional capital costs	Rs 37,750						
Working life	12.5 years						
=> Annuity factor		0.091	0.103	0.116	0.129	0.144	0.158
=> **Annualised additional capital costs**	Rs	3,443	3,896	4,378	4,888	5,422	5,980
Annual (seasonal) operating costs, (irrespective of discount rates)	Rs 22,350	22,350	22,350	22,350	22,350	22,350	22,350
=> **Total annual costs**	**Rs**	**43,623**	**48,529**	**53,959**	**59,847**	**66,122**	**72,713**
Corresponding annual benefits	**Rs**	**84,312**	**84,312**	**84,312**	**84,312**	**84,312**	**84,312**
Benefit-cost ratio		**1.933**	**1.737**	**1.563**	**1.409**	**1.275**	**1.160**

Furthermore, the bioreactor could also be operated for the rest of the year, i.e. during the non-pulping seasons, on other biomass, thereby improving the profitability. Since the estate has a connected load of 215 kW, for both processing of coffee beans as well as for spraying and lifting of water, the electricity generated would help power this equipment.

Conclusions

The bioreactor-biogas route of effluent treatment thus provides not only a solution to waste disposal, but also an alternative fuel for electricity generation, so that, in the absence of adequate "costs" imposed on polluted effluent discharge and on the use of water, positive returns on investment are obtained through replacement of diesel.

Pollution Control Boards (PCBs) of Indian states have already stipulated conditions for effluent discharge through their Water (Prevention & Control of Pollution) Acts. But adequate environmental policy enforcement would be required to ensure that these standards are maintained.

An alternative is to utilise the existing potential for substances in coffee wastewater -- sugars, starches and other dissolved organic matter -- to be converted to usable forms. This paper has considered a waste-to-energy conversion route for coffee-effluent treatment. It includes pH neutralisation of the effluents followed by anaerobic digestion, and collection of the biogas so generated. This gas can then be profitably used in dual-fuel engines for the generation of electricity. The case study has shown that the financial returns from the avoided diesel costs in the current oil-pricing scenario[13] more than justify the investment in the effluent treatment process.

The bioreactor system also includes provision for a part of the water content to be recycled for non-potable uses. If this water were priced, it could be evaluated; at present, it constitutes a tangible benefit that should be included in the reckoning.

Ecologically benign and efficient treatment and disposal of wastewater from wet coffee processing is a problem that has to be solved in coffee processing regions. There are several effluent treatment processes. But the investment in these processes can be made attractive through pecuniary returns instead of being forced through environmental protection laws.

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Annexe: 1

Consent conditions stipulated by Karnataka State Pollution Control Board (KSPCB) under the Water (Prevention & Control of Pollution) Act 1974

1. The daily discharge of trade effluent shall not exceed a specified number of litres per day (LPD).
2. The daily discharge of trade effluent shall not contain constituents in excess of tolerance limits laid down in Table 13, before discharging for on-land irrigation or for sun drying pits (Solar Evaporation).
3. The industry shall provide neutralisation tank of 1 day capacity (lime addition) followed by anaerobic lagoon of 21 days capacity (Minimum depth 3.0 meters) aerobic lagoon of 7 days capacity (Maximum depth of 1.2 meters) and setting tank of 1 day capacity before discharge, for on-land irrigation and final treated effluent shall confirm to the standards stipulated in Table 13.
4. The industry shall adopt water-recycling system generated from pulping and washing to the maximum extent so as to reduce the wastewater generation for treatment.
5. The solid wastes generated in the form of husk shall be removed by screen installed before neutralisation tank, the husk removed to be dumped in a pit for scientific method of composting. Smell nuisance shall be completely avoided.
6. Occupier shall provide any dry pulper to avoid wastewater generation. Please note that, by using this system, wastewater generation can be reduced by 70%. Any new technology involving water conservation is suggested.
7. Occupier shall ensure that, sludge generated in the lagoons is removed at least once in a season.
8. Occupier shall not discharge either treated or untreated effluents directly into the natural water sources at any cost.
9. Any method of water conservation may be undertaken to reduce pollution by effluents, including the evaporation (sun drying pits) method.
10. Inner surface of anaerobic and aerobic lagoons may be temporarily lined by providing 2.5 cm thick puddle clay with plastic sheets in respect of small estates (up to 10 ha.), but construction should be pukka in respect of big and company estates.
11. In water logged area treatment units are to be constructed above the ground level.

Table 13: Tolerance limits for the treated trade effluents to be discharged on land for irrigation

	Parameters	Tolerance limits
1.	Colour and odour	See note
2.	pH value	6.0 to 9.0
3.	Suspended solids	200 mg/litre
4.	BOD	100 mg/litre

Note: All efforts should be made to remove colour and odour as far as possible

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Endnotes:

[1] US$ = Rs 47 approximately during that period.

[2] The coffee export trade was totally deregulated in 1996. The buyers of Indian coffee are chiefly Russia, Italy, Germany, the USA, Japan, Poland, Netherlands, Spain, Slovenia, Belgium, and countries of the Middle East.

[3] Effluents of industrial processes and sewage treatment usually have high water content hence the term "wastewater" is used to describe these products.

[4] The biological oxygen demand (BOD) is the amount of dissolved oxygen aerobic organisms need to carry out oxidative metabolism in water containing organic matter. Chemical oxygen

demand (COD) is the amount of dissolved oxygen required to combine with chemicals in the water; it is a measure of the oxygen equivalent of that portion of organic matter that is susceptible to oxidation by a strong chemical oxidizing agent.

[5] This is the result of a new strategy for the co-operation between Norway and India (2001) prepared by the Ministry of Foreign Affairs of Norway in the area of environment, available at http://www.nlh.no/noragric/publications/reports/rep1B_bodytext.pdf

[6] The digester consists of a reinforced concrete structure covered with a specially constructed vault.

[7] The data collection for the case study was undertaken jointly by IEI and EnSol Power in July 2002.

[8] Personal communication with Dr H.N. Chanakya, ASTRA, Indian Institute of Science, Bangalore

[9] These rates are from sub-section (2) of Section 3 in the Water (Prevention and Control of Pollution) Cess Act 1977 and sub-section (2A) of Section 3 in the Water (Prevention and Control of Pollution) Cess (Amendment) Act, 2003.

[10] The specific fuel consumption per kWh generated through a diesel engine (according to the Kirloskar Manual) is 0.265 kg or 0.0.304 litre, under test conditions; assuming an efficiency of 80% in average field conditions, the diesel consumption would be 0.381 litre/kWh.

[11] Term loans provided by financial institutions for such projects are usually for a period of 10 years.

[12] This is the least period during which the project can be safely expected to run.

[13] This does not include the price increase announced on the 16th June 2004.