HOUSEHOLD WILLINGNESS TO PAY FOR IMPROVED SOLID WASTE MANAGEMENT IN OSUN STATE, NIGERIA

[1] Adepoju, A. A., and [2]Salimonu, K. K
[1]Department of Agricultural Economics, Ladoke Akintola University of Technology, Ogbomoso Oyo Nigeria. E-mail: busola_adepoju@yahoo.com
[2]Department of Agricultural Economics, University of Ibadan, Ibadan, Oyo Nigeria.

Key words:
willingness to pay, solid waste, improved service, Osogbo metropolis

Abstract
Environmental quality value can be estimated from what people are willing to pay (WTP) to improve or to restore their environment, using valuation techniques which measure peoples' preferences. The study examined the general features of the existing solid waste management, household willingness potential for improved waste disposal, identified the socio economic variables and other factors influencing WTP for improved waste disposal services. Primary data collected from 120 households in Osogbo metropolis, was analysed using descriptive statistics and logit regression model. The result reveals that 65 percent of the respondents are male while 67 percent are married with an average household size of 4 members. Majority of the respondents are in their active age with mean age of 42 years. Most of the respondents have formal education, the average years of education is 5 years. Fifty-three percent of the respondents are engaged in the civil service as their primary occupation. About 37 percent of the households dispose their solid waste through burning, while 60 percent claim to dispose off their waste on a weekly basis. Irrespective of non-reliability of waste vendors, 52.5 percent of the respondents paid between ₦400- ₦600 monthly to dispose waste. Majority of the households (87 percent) are willing to pay for improved waste services while most of the respondents will be willing to pay less than 5 percent of their monthly income on waste management services. The logit result reveals that sex, household expenditure and years of education are statistically significant at 10, 5 and 1 percents respectively while other factors are insignificant statistically. It was recommended that programmes that will facilitate investors (private sector) in waste disposing be initiated while payment for this service should be made affordable to encourage those households that are willing to pay.

INTRODUCTION

Solid wastes by definition include refuse from households, non-hazardous solid waste from industrial and commercial establishments, refuse from institutions market waste, yard waste, and street sweepings [7 and 4]. Broadly, Household wastes otherwise known as residential or domestic wastes are made up of wastes that are consequences of household activities. These according to [6] include food preparation, sweeping, cleaning, fuel burning and gardening wastes old clothing, old furnishings retired appliances, packaging and reading materials, and where diapers or bucket latrines are used, household waste include faecal material.

In Nigeria, many metropolises are faced with the problems of rapid expansion due to population increase and this, no doubt, brought increasing strain on urban infrastructure facilities. One area in which this strain has become obvious is in waste management where the existing system appears to be incapable of coping with the heap of waste generated on daily basis. The urban centers are experiencing an increased rate of environmental deterioration, with refuse dumped along drainage channels. Most cities in Nigeria are faced with waste management problems, and Osogbo is not exempted.

Attempts have been made by scholars, researchers, consultants and government to determine the actual amount of waste being generated in Nigeria in general [3]. In a survey carried out by [6] on waste generation in Nigeria. The study shows that the volume of wastes generated by all the states increased over the period between 1994 and 1996. It was estimated that by the year 2010, Nigeria will generate about 3.53 million tonnes of solid waste, based on a per capita solid waste generation of 20kg per year [3].

Nigerian cities have been described as some of the dirtiest, the most unsanitary and the least aesthetically pleasing in the world [4]. This is because some individuals are dirty, this evidence can be seen everyday by way of indiscriminate discharge of garbage into drains and the highways. About 75 percent of solid waste collected in most Nigerian cities is disposed in open dumpsites. This method which is rampant is improper as it is not aligned to the sanitary landfill recommended. It marginalizes the urban environment as a result of the negative externalities it generates [17 and 2]. In corroborating this assertion, [6], stated that the decomposition of wastes on dumping grounds emit intolerable smells and attract potential diseases. The dumpsites, which are poorly maintained, are also a source of pollution and a cause of poor urban aesthetic [6].

The economic importance of waste management on the quality of life cannot be over-emphasised. Wastes that are not well managed can affect the environment in terms of the contamination of the atmosphere, soil and water. This can cause severe problems for humans and animals population. It can also affect human health in particular by causing convulsion, dermatitis, irritation of nose/throat, anaemia, skin burns, chest pains, blood disorders, stomach aches, vomiting diarrhoea and lung cancer which may lead to death [4]. It is worthy to note that it breed flies (which carry germs on their bodies), mosquitoes, and rats which aids salmonella, leptospirosis and other diseases they cause by biting and spoiling millions of tons of food. Lastly, is the social effect where flood may occur as a result of dumping of refuse in drainage especially during the raining season; an example of this is the recent flood which happened in late July 2010 in Osogbo metropolis. Lives and properties worth millions of naira were lost in this July flood [10].

Problem Statement.

Collection of waste used to be the responsibility of municipal authorities in the past [9], hence, waste collection is a service for which local government is responsible [7]. In short, waste collection is the constitutional responsibility of the local government. This responsibility is not mutually exclusive, because, there is no local government area in Nigeria that can afford the huge financial, technical, administrative and human resource requirements to effectively carry out this constitutional responsibility [4]. The collection of solid wastes in many Nigerian cities has always until very recently, been dominated by government agencies; it has been concluded that it is the responsibility of government to solve the waste collection problems, as part of government obligations to the citizens.

An explanation for the inability of the government to manage solid waste collection effectively arose perhaps from the misconception of this task as a public good. Irrespective of the fact that government gave waste collection a priority in their development objectives, their ability to curtail the problems of waste collection deteriorates with time, due to rising capital costs for plant and equipment, increasing operation and maintenance costs. Considering the rapid spatial and population growth of most urban areas with decreasing coverage levels, and with increase in level of waste generated, confronted by increasing public demand for improved services [12 and 13], the need arises for the involvement of the private sector and the civil society in the provision of municipal solids waste service. It should be noted, however, that it is only in the large urban centres of Nigeria e.g. Lagos, Ibadan, Warri, Suleja amongst others that the activities of formal private sector are recorded [4]. In majority of the secondary cities such as Osogbo, they are neither totally absent or being substituted with the informal refuse collectors such as cart pushers. This therefore gives rise to the need to evaluate the household willingness to pay for improved solid waste disposal services in the study area. Specifically the study examined the general features of the existing solid waste management, household willingness potential to pay for improved waste disposal, identified the socio economic variables and determine the factors influencing WTP for improved waste disposal services.

Methodology

Data collection and sampling technique: The study was carried out in Osogbo metropolis. Osogbo is the capital city of Osun State, Nigeria. It is therefore a centre of administration. Two major local government areas (LGAs) are located in Osogbo namely Olorunda LGA and Osogbo LGA. The third, however, is Egbedore LGA having about two-fifth of its land coverage within the Osogbo metropolis. Osogbo metropolis has a population of approximately 350,000 people according to the 2006 National population census. It lies on the tropical rainforest with both favourable rainfall and adequate soil. It has an annual rainfall of about 1130mm covering a period of 200-220 days each year. The study area was selected because it is the centre of administration of Osun state and by this status has experienced expansion due to population increase.

The study used primary data. The data were collected with the use of structured questionnaires. A two stage sampling technique was used to select households used for the study. The first stage involves stratifying the entire study area into new and old areas. The study covers three locations in each of the two areas. The locations covered in the new area include Agunbelewo, Odekale and Ataoja Estate while locations covered in the old area are Oke-onitea, Jaleyemi and Dada Estate. Twenty households were randomly selected from each of the locations and this forms the second stage. A total of 120 households were sampled from both areas, i.e. sixty households from the old area and sixty households from the newly developed area.

Descriptive statistics such as frequency distribution tables, mean and standard deviation were used to analyze the socioeconomic characteristics of the respondents. The logit model was used to determine the mean willingness to pay for improved waste disposal service by households. The logit model which is based on the cumulative probability function was adopted because of its ability to deal with a dichotomous dependent variable on a well established theoretical background. Logistic regression, according to [11] is a uni/multivariate technique which allows for estimating the probability that an event will occur or not through prediction of a binary dependent outcome from a set of independent variables. The model specified by [8 and 15] was adopted for this study as used by [5] in a study on willingness to pay for improved conservation of environmental species in the USA and [17] on willingness to pay for improved household solid waste management in Ibadan North Local Government Area, Oyo State.

Willingness to pay(WTP) of the households for improved waste disposal services

The logit regression model specified below was used to obtain the willingness to pay of the households for an improved water supply. The coefficient estimates obtained were then used to calculate the mean willingness to pay of the households as used by [1].

$$P_i = E(Y = 1/X_i) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_i)}} \qquad ---1$$

Where P_i is a probability that $Yi = 1$

X_i is a set of independent variables

Y is dependent variable

$ß_0$ is the intercept which is constant

$ß_1$ is the coefficient of the price that the households are willing to pay for improved water supply

Mean willingness to pay for improved waste disposal by households was calculated using the formula derived by [3] and given as:

$$MeanWTP = 1 * In \frac{(1 + \exp^{\beta_0})}{/\beta_1/} \qquad ---2$$

where $ß_0$ and $ß_1$ are absolute coefficient estimates from the logistic regression and the *Mean WTP* is the mean for the improved waste disposal by households.

Factors influencing willingness to pay by household: To identify the factors influencing willingness to pay for improved waste disposal by households, the household responses to the WTP question was regressed against the households WTP potential and other socioeconomic characteristics of the household. The regression logit model is specified as:

$$Y = \frac{1}{1 + \exp^{z}} \qquad ---3$$

Where Y = responses of household WTP which is either 1 for Yes and 0 for No

$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 .... + \beta_7 X_7$

$Z = ß_0 + ß_1 X_1 + ß_2 X_2 + \ldots\ldots\ldots\ldots\ldots + ß_7 X_7$

X_1= Sex (Dummy: Male=1, Female= 0)

X_2 = Age (yrs)

X_3 = Educational level (number of years spent in the school)

X_4 = Marital status. Dummy variable (married =1, single=0)

X_5 = Household size (number)

X_6 = Percentage WTP from income (number)

X_7 = Household expenditure (₦)

The pseudo-*R* square and the chi-square were used to measure the goodness of fit of the model and the significance of the model used.

Discussion of the Results

The socio economic characteristics of the respondents are presented in table1. The male accounted for 65 percent while 35 percent were female. The high percentage of the male is as a result of sampling of the household heads. The proportion of the married in the study area is 67 percent which may therefore encourage the willingness to pay for improved solid waste considering the volume of waste from members of the household. The household size distribution showed that 70 percent of the respondents have between 1-5 household members while only 5 percent represent those that have above 10 members. The mean household size of the respondents is 4 members. The age range with the highest frequency is 41 – 50 years which accounted for 35 percent of the respondents while those above 60 years accounted for 3.3 percent. The average age in the study area is 42 years. This implies that respondents are in their active age and therefore can work to earn, more income which can affect their decision to pay for improved waste services.

About 10 percent of the respondents represent those without formal education while only 5.8 percent of the respondents had post graduate education. The mean years of education in the study area is 5years. This revealed that a typical household in the study area had at least 5 years of formal education. Education helps to enlighten the respondents on the need to keep our environment clean, free from germs and healthy for all. The primary occupation of the respondents revealed that 54.2 and 20 percents engaged in civil service and trading respectively while only about 7.5 percent were involved in other income activities such as transportation, attendants in eatery, fuel stations etc .

Household expenditure on food and non-food was used as a proxy for income s most respondents would otherwise not divulge the real value of their monthly income [1]. The level of household expenditure is generally low, about 51.7 percent of the respondents spent on a monthly basis about ₦20,000 or less as household monthly expenditure while about 12.5 percent spent over ₦60,000 as monthly expenditure. The average household expenditure was about ₦26,655, with the lowest and the highest being ₦6,800 and ₦108,500/month/household respectively. The result reveals the level of earnings of respondents as they are not likely to spend above their income. As the level of income increases, the probability that households would adopt improved waste disposal services will also increase.

Table I: Socio economic characteristics distribution of the respondents

Socio economic		Frequency	Percentage	Mean value
Sex	Male	78	65.0	
	Female	42	35.0	
Marital Status	Married	81	67.5	
	Single	39	32.5	
Household Size	1-5	84	70.0	**4**
	6-10	30	25.0	
	Above 10	6	5.0	
Age (yrs)	≤ 30	24	20.0	**42**
	31- 40	40	33.3	
	41 -50	42	35.0	

51- 60	10	8.3	
above 60	4	3.3	
Education (yrs) None	12	10.0	**5**
1-6	54	45.0	
7-12	27	22.5	
13- 18	20	16.7	
>18	7	5.8	
Pry Occupation Civil service	65	54.2	
Farming	10	8.3	
Trading	24	20.0	
Artisans	12	10.0	
Others	9	7.5	
Monthly expenditure <20,000	62	51.7	₦26,655
20,001- 40,000	25	20.8	
40,001- 60,000	18	15.0	
Above 60,000	15	12.5	

The general method of disposing waste, its reliability as well as the frequency of waste disposal is presented in Table II. The result revealed that 37.5 percent of the respondents claimed to dispose their waste through burning which helps to keep the environment clean. On the reliability of use of this method, 80 percent attested that it is a reliable means of disposing their waste. On another hand, 35 percent of the respondents dispose their waste by dumping it on the roadside, at a dump site, or a nearby bush. However, 54.8 percent of this category indicated that it was not a reliable means of disposing their waste. Twenty five percent of the respondents used waste vendor (waste collector) by paying a token to dispose their refuse, but 63 percent of this category also claimed that was not a reliable means of disposing waste because of the limited number of waste vendor. Lastly, only 2.5 percent of the respondents bury their waste in the soil and they all claimed that the method is reliable to dispose their household waste.

The frequency of disposing waste showed that while 14 percent dispose waste daily, about 60 percent of the respondents dispose their waste on a weekly basis and only 2.5 disposed occasionally. With the knowledge that keeping household waste in the house for a week long has its health implication because it can harbour germs, breed rats, mosquitoes, cause air pollution amongst others. Given this result, households may be encouraged to pay for improved, prompt and regular waste disposal through the private sector.

Table II: Method of Solid waste disposal, reliability of methods and frequency of disposal

Variable	Frequency	Percentage
Method Burning	45	37.5
Use Of Waste Vendor	30	25.0
Dump Nearby	42	35.0
Bury In The Soil	3	2.5
Total	**120**	**100**
Reliability Of Method (Yes=1)		
Burning	36 (9)	80 (20)
Use Of Waste Vendor	11 (19)	36.7 (63.3)
Dump Nearby	19 (23)	45.2 (54.8)
Bury in The Soil **Frequency**	3 (0)	100 (0)
Of Disposal		
Daily	17	14.2
Weekly	72	60.0

Bi-weekly	12	10.0
Monthly	16	13.3
Occasionally	3	2.5
Total	**120**	**100**

Figures in parenthesis represent the claim that the methods are unreliable and the corresponding percentage

Table III present the distribution of the current expenditure on waste disposal and the willingness to pay potential of the household. The result revealed that 52.5 of the respondents spend between ₦400- ₦600 on waste disposal per month. While 7.5 percent claimed to dispose waste at no cost, only 3.3 percent spent above ₦ 800 on waste disposal. This is an indication that majority of the respondents are already expending money on solid waste disposal and therefore may be WTP for improved services. A binary response to household willingness to pay for improved services showed that 87.5 percent are willing to pay. However, 71.4 percent of this category of respondents are willing to pay only less than 5 percent of their monthly income to waste collectors while only 3.8 will be WTP above 10 percent of their income if the need arise. The mean value of the percentage of income the respondents are WTP is 3 percent. Given the advantages of improved services, most households in the study are WTP a proportion of their income, to sanitise their immediate environment.

Table III: Household Current and Proposed Expenditure on Waste Disposal

Expenditure (₦)		Frequency	Percentage
Current	None	9	7.5
	<400	29	24.2
	401- 600	63	52.5
	601- 800	15	12.5
	above 800	4	3.3
	Total	**120**	**100**
Household WTP	Yes	105	87.5
	No	15	12.5
	Total	**120**	**100**
WTP Potential	< 5%	75	71.4
	5-7.5%	21	20.0
	7.5- 10%	5	4.8
	above 10%	4	3.8
	Total	**105**	**100**

Determinants of WTP for improved waste disposal services: Table 4 presents the logit analysis of the factors that determine the willingness to pay for improved waste disposal services. The results showed that respondents' age, marital status, household size and percentage household WTP potential do not significantly influence the willingness to pay for improved waste disposal. However, sex, educational status, and monthly expenditure of households are statistically significant at $P < 0.10$, $P < 0.1$ and $P < 0.05$ respectively. Educational level is positively related to WTP for improved waste disposal services. This indicates that as level of education increases the tendencies to adopt and pay for improved disposal services will also increase. The coefficient of household expenditure, a proxy for income is also positive, an indication that increase in income will increase the probability that households would be willing to pay for improved disposal services. This is confirmed by [14 and 16], The result reveals that the marginal effect on probability of households paying for the service with respect to household monthly expenditure is 0.46776. This implies that for every ₦1 increase in household monthly expenditure, the likelihood of paying for improved refuse collection and disposal increases by 0.46776.

Table IV: Multivariate Logit Regression.

Variable	Marginal effect on probability of willingness to pay Coefficients	Standard Error	Z-statistics
Constant	8.18259	1.510	0.3112
Sex	-2.25270	-1.827	0.0677*
Age	-9.82100	-1.159	0.2463
Educational level	0.33107	3.105	0.0019***
Marital status	0.96002	0.924	0.3554
Household size	0.53208	1.782	0.0747
WTP Potential	0.18453	1. 245	0.2133
Expenditure	0.46776	2.185	0.0289**

***	Statistically significant at 1%	Chi-squared (LR statistic)	22.36494
**	Statistically significant at 5%	Degree of freedom	7
*	Statistically significant at 10%	Significance level	0.00000
	Log likelihood -20.84719	Restricted Log likelihood	-32.03139

Conclusion and recommendations

The study revealed that payment for waste disposal is not a new idea in the study area, however, majority of the respondents were willing to pay for an alternative waste disposal services, particularly when it is going to be an improvement on the existing means of services. Sex, education and household expenditure were discovered to be determinants of household WTP for improved disposal services in the study area. It is recommended that programmes facilitating investors in waste disposing be initiated while payment for this service should be made affordable to encourage those households that are willing to pay. In addition, public enlightenment campaign through mass media could also be adopted in order to properly inform the citizens on the need to patronize the solid waste disposal investors.

REFERENCES:

[1] Adepoju AA & Omonona BT (2009): Determinants of Willingness to Pay for Improved Water Supply in Osogbo Metropolis; Osun State, Nigeria. *Research Journal of Social Science,4:16*

[2] Adinnu, IF (1994). 'Landfill and Urban Residential Rental Values: A Case Study of Achapo landfill facility in Ojo LGA, Lagos State'. *Unpublished MURP Dissertation.* Centre for Urban and Regional Planning, University of Ibadan.

[3] Agbola, T (2001). 'Turning Municipal Waste into Compost: The Case of Ibadan'. In Drechsel, P. and D. Kunze (eds), *Waste Composting for Urban and Peri- Urban Agriculture Closing the Rural-Urban. Nutrient Cycle in Sub-Saharan Africa,* International Waste Management Institute, Food and Agriculture Organization of the United Nation, CABI publishing, OXon, UK,pp. 69-81.

[4] Alabi, M (2004): Waste Products Survey For Identification and Quantification Of Different Wastes Generated In Nigeria. An Unpublished PhD Thesis in the Dept of Geography, University of Ibadan

[5] Branka T & Kelly G. [2001]: Contingent valuation willingness to pay with respect to Geographically nested samples: Case Study of Alaskan Steller Sea Lion". 2001 W-133 Western Regional Project Technical Meeting Proceedings. pp 2-4.

[6] CASSAD (Centre for African Settlement Studies and Development) (1998). Workshop on Turning Waste to Weath-Strategies, Options, Appropriate and Affordable Technology for Waste Management, Training Module Prepared Course Codes CASTWW/98 April

[7] Cointreaus-Levine, S. (1994). *Private Sector Participation in Municipal Solid Waste Services in Developing Countries Volume 1. The Formal Sector.* Published for Urban. Management Programme by The World Bank, Washington, D.C.

[8] Hanemann M. [1989]: Welfare evaluations in contingent valuation experiments with discrete responses data. *American Journal of Agricultural Economics* ***71****(Nov.):1057-61.*

[9] Harris, PJC, M. Allison, G. Smith, HM. Kindness and J Kelley (2001). 'The Potential Use of Waste – stream Products for Soil Amelioration in Peri-urban Interface Agricultural Production Systems'. In Drechsel, P. and D. Kunze (eds), op.cit., pp. 1-28.

[10] Osun mail (2010): Flood of Tears in Osogbo. An Authoritative Weekly Newspaper in Osun State. www.osunmails.com/?p=848

[11] Roopa KS [2000]: Qualitative choice and their uses in environment economics. Land Economics **90** (4):499-506.

[12] Salifu, L (2001). 'An Integrated Waste Management Strategy for Kumasi' In: Drechsel, P. and D Kunze (eds), op.cit., pp. 112-114.

[13] Sule, RAO (1981). 'The Deterioration of the Nigerian Environment Solid Waste Disposal in Metropolitan Lagos, *Geojournal*, **3**: 57-77.

[14].Wasike WSK, and Hanley N. [1998]: The pricing of domestic water services in developing countries: A contingent valuation application to Kenya. *Monograph*.

[15] Whittington D., Briscoe J., Mu X. and Barron W. [1990]: Estimating the willingness to pay for water services in developing countries: A case study of the use of contingent valuation surveys in Southern Haiti. *Economic Development and Cultural Change* ***38*** *No.2 (January) 293-311.*

[16] World Bank Water Demand Research Team. [1993]: The Demand for Water in Rural Areas; Determinants and Policy Implications. In *The World Bank Research Observer*, **8** (1) 47-70..

[17] Yusuf, SA, Ojo, OT & KK (2007). Households' Willingness to pay for improved household solid waste management in Ibadan –North LGA of Oyo State, Nigeria. J. of Environmental Extension University. of Ibadan. Vol: **6** pp 57-63.

Placer Mining and the Guyana Environment

Dalgety W. T.
Director, Guyana Geology and Mines Commission GGMC, Georgetown, GUYANA
E-mail: tdalgety@yahoo.com

Key words: placer, sluicing, tailings, solid waste and sanitation, process, reclamation.

Abstract
This paper is prepared by a Director on the Board of the Guyana Geology and Mines Commission (GGMC) based on his visits to gold and diamond mining operations in rivers and riversides in Guyana. Gold mining is an important source of income for small and medium scale producers and the nation. The paper gives an overview of gold mining operations, challenges and the approach to solutions to these challenges. This includes a discussion of tailings management; solid waste management and sanitation; process improvement; reclamation. The international call to desist from the use of mercury gives rise to the need for greater consideration of all factors that lead to sustainability. Greater collaboration between West African and Guyanese miners is recommended based on shared geological history when millions of years ago the Precambrian Shield of Guiana and south West Africa was one land mass.

INTRODUCTION

One of the most striking physical features of Guyana which occupies the North Central corner of South American is its rivers. Most of Guyana‟s main rivers either flow East such as the Potaro, Mazaruni and Cuyuni rivers; or they flow North such as the Essequibo, Demerara and Berbice rivers. Geologically, Guyana is on the northern province of the Amazon Craton or land mass.

Gold is a heavy mineral with a specific gravity of 19.3. It occurs in all of Guyana‟s rivers that flow east from the Pakarima Mountain range to the Essequibo River - notably the Potaro and Mazaruni rivers and their tributaries. Placer deposits are observed on most of the main rivers draining the greenstone terrain which hosts the majority of the primary gold. Lode gold is frequently found in Precambrian terrains [1]. The Precambrian rocks are meta-volcanic and meta-sedimentary. A compilation of 135 types of deposits worked and observed in Guyana by Bernard (1990) showed that within the major gold occurrences in parts of Guyana (Barama-Mazaruni terrain):

40% of the mineralised area lodes are within greenstones and meta-sediments
30% of the in-situ deposits are near granite-greenstone contact zone
20% of the placer deposits occur over greenstone regions
10% are in other deposits including alluvial deposits and lodes in granitic and gneiss rock [2].

Guyana‟s rivers became waterways for gold-seeking „pork-knockers‟ (small scale operators working cooperatively) immediately on Emancipation of African slavery in 1838. Hassan Arero, Curator, Africa, Oceania and the Americas Collection, British Museum mentions how highly gold is esteemed by Africans not only for status and wealth but also as a symbol of mental, physical and spiritual protection. Guyanese esteem gold similarly – protection, wealth, status, power, and bonding of the genders [3].

Guyana has six mining districts. W. T. Dalgety was appointed on February 26, 2004 to be a Director on the Board of Directors of the Guyana Geology and Mines Commission (GGMC). He then began visiting gold and diamond works of native miners. He has visited operations at Frenchman Creek, Mahdia and Omai in Potaro Mining District #2, Puruni, Oranapi and Aruwai in Mazaruni Mining District #3, Groete River and Aurora in Cuyuni Mining District #4, and Purple Heart Gold Mine in Arakaka in North West Mining District #5.

This paper presents an overview of gold mining in Guyana, some challenges caused by mining operations and the numerous ways these challenges are being addressed. This includes a discussion of tailings management; solid waste management and sanitation; process improvement; reclamation. The basis for establishing relations with West African gold miners is also discussed.

OVERVIEW of GOLD MINING IN GUYANA

Figure 1, Cutterhead

ile)

In Guyana, gold is mined by two methods: river dredging and land dredging. River dredging technology is described as cutterhead, suction, and missile. All three employ the force of suction to transport gravel from river bed to the surface for processing. Cutterhead is a mechanical cutter used to disintegrate compacted gravel before it is sucked to the surface (figure 1). Suction dredging involves a diver on the river bed with flexible hose to suck up loose gravel, sand and mud. Missile dredging uses a diver-less nozzle to suck up unconsolidated gold bearing gravel (figure 2). Land dredging technology is subdivided into a) hydraulicking (or jetting), b) dry mining. Dredge sizes range from 3 inch to 14 inch and this represents the diameter of the gravel pump feeding the ore to a sluice box. The popular size is the 6 inch. The process technology used to recover gold by either river or land dredging is called sluicing.

River Dredging:

A river dredge is a floating gold processing plant. First, a pontoon is constructed of wood, empty oil drums, or steel. The pontoon supports equipment. The essential equipment is a 6-cylinder engine, an impeller pump, cutterhead, suction nozzle, or missile nozzle, a sluice box fitted with fur mat, expanding metal and magic mat, a lavador, a battel, a gold retort, a gold scale and mercury. Nearly all river dredges are designed and fabricated in Guyana. In addition to the essential equipment, the pontoon supports kitchen and living space for workers.

In river dredging, the „tailings“ is deposited into the river. However, direct discharge of tailings into a river or creek without the permission of the Commissioner of the GGMC is an offence because this redistribution of tailings can cause navigational problems if not adequately managed. The critical turbidity of a river in Guyana is 30 NTU (Nephelometric turbidity Unit). However, “operators shall ensure that discharge from a tailings pond or a dredge into any river or creek shall not exceed 100 mg/L or 50 NTU,” Reg.240 (3)(b)(i) and (ii)/2005 [4].

Land dredging:
Hydraulicking (or jetting) operation: The essential equipment in hydraulic mining (jetting) is two 6-cylinder diesel engines, a gravel pump, a pressure pump, hoses, a sluice box fitted with fur mat, expanding metal, and magic mat, a lavador, a gold scale, a battel, a gold retort, and mercury [5].

Two engines are used in this method of mining. One engine is used to pump water from a river, creek or stream to the mining site and the other engine is used to suck ore from a sump called the “marack hole” to the sluice box. With one engine, high pressure water jets are directed to the gold bearing earth. These jets disintegrate loose material like sand, loam, clay and gravel making it “slurry”. This slurry is channelled into the “marack hole”. From there, the second engine with the gravel pump “sucks up” the slurry onto the Sluice Box where the gold is trapped. The washing cycle called “wash down” follows.

Dry mining operation: Dry mining equipment includes excavators, bulldozers and loaders. Excavators and bulldozers are used to transport the gold bearing earth towards

	Surface Grading (Gold)
1.2m	Grading Gravel (Gold)
1.8m	Sandy Gravel (Gold)
2.7m	Formation of fine Stringers (Gold)
6.1m	Large Stringer Formation mixed with a Black rock that has gold. The stringer stones are good for crusher.
12.2m	Large Brown & white reef stones (very wide) - these are the ones broken with sledge hammers for the mill.
18m	Below 18m there is a yellow rock which is the real pay (3-4 dwt per battel)
30m	Presently Purple Heart (May) is about 30 meters deep. At this dept

GGMC says it`s too dangerous for hydraulicking (Jetting).

Figure 3, Profile of the claim "May" (Purple Heart)

the "marack hole". This mining method allows for several choices because not only loose material is mined but also indurate cemented material. A profile of the Purple Heart mine which includes "hard rock" dredge mining is shown in figure 3. The Higgins family who own Purple Heart Mine in Arakaka, Mining District #5, has overcome several challenges since 1983 when the mine began production. There, gold was recovered from within the first two feet of the ground, then in the sand, gravel, saprolite, and indurate cemented rock. Stone was broken by men using sledge hammers. A hammer mill is employed to crush stones and extract gold from them.

In other dry mining processes different from Purple Heart, the pay gravel is generally stockpiled and washed into the "marack hole" via a washing plant. Washing plants are vibrating screens fitted with transverse jets or jetted manually by miners. A back hoe feeds the screen with pay gravel. The washing plant is normally very near the "marack hole". After this stage is the sluicing operation.

Sluice Box Processing i.e. "wash down": Since the 1850s, sluicing has been the preferred method of capturing gold in Guyana. According to Karen Livan, "The sluice box is essentially an open section of a box with a sloping channel and some form of riffling or matting to collect the concentrate. Sluice boxes are of low capital cost and require low operating costs and simple to construct. The gold is trapped on the matting at the bottom of the sluice box. A pre-concentrate from the sluice box is gained by washing the mats in water and collecting the concentrate in a container. The pre-concentrate from the sluice box is further upgraded using a battle or gold pan" [6]. The concentrate from the gold pan / battel is upgraded by amalgamation with mercury. The final concentrate which is amalgamated gold (amalgam) is then transferred to a cotton cloth. The cloth is squeezed to recover excess mercury leaving the amalgam. The squeezed amalgam is transferred to a retort and heated to recover gold as a residue.

CHALLENGES and DISCUSSION OF APPROPRIATE SOLUTIONS

In land dredging where ancient river beds are mined with water in a tropical rainforest environment there are many challenges. Karen Livan wrote, "In a small scale operation alone, a single land dredge in Guyana moves about 130 tons of material daily. At about 1000 operating dredges in the country, about 130 million tons of alluvial is moved daily during the mining of gold and diamonds. At most of these operations, often there are no adequate tailings management plans and hence much of the fine particles from the materials moved by the dredges end up in the creeks, streams, and rivers".

The challenges caused by handling and processing such large quantities of mud, sand and stone for gold include siltation of rivers, turbidity of waterways, navigational problems and mercury contamination of potable water. These may result in depletion of fish stock and diseases. The responses to these challenges are proper tailings management, proper solid waste management with enforceable sanitation regulations, improved processing and retorting, and reclamation. Urgently, sustainability has to be the watchword to ensure livelihoods are sustained while wealth is pursued.

GGMC is working towards sustainable mining. GGMC describes sustainable mining as "present mine development that does not compromise the resources that are available to present and future generations" [7]. GGMC identifies elements of sustainable mining to include: exploration, feasibility study or assessment, environment and social impact assessment for large scale mining operations, environmental management systems for large and medium scale operations, mine planning, environmental management planning, mining with environmental management, mine site reclamation and closure".

The mineral licence holder in Guyana sets up operation to make money. Unless he/she is made aware and convinced of the short and long term social and environmental dangers based on traditional practices, and made to consider them, he/she would cut corners for an extra dollar. Licence holders need to be persuaded to want to change. The regular science and legal staff of GGMC cannot systematically monitor practises at all locations. In 2002 there were about 1000 operating dredges but by the end of 2009 the number had increased to about 2400. Visits made by W. T. Dalgety reveal the need for improvements in tailings management, solid waste management and sanitation, processing and retort technology and reclamation.

Tailings Management: Tailings discharges for more than 2000 operating dredges places an environmental stress on Guyana‟s waterways. In 2008 a mining manual was prepared and distributed by Guyana Environmental Capacity Development (GENCAPD) giving a guide to water management, pond development and design features, self-monitoring and guidance on how to make and use a simple turbidity tube for water quality testing [8]. The Mining (Amendment) Regulations 2005 spell out requirements for managing tailings, turbidity including daily monitoring of turbidity of tailings discharge. Tailings should not be directly released into streams, creeks and rivers unless the Total Suspended Solids (TSS) is below 100mg/l. Suspended solids absorb heat from sunlight making the waterways warmer – thus reducing the oxygen available for living things. Suspended solids can also destroy the habitats of spawning fish and pose severe hardships for communities that live down river from mining communities. Many Small and Medium Scale miners must be commended for the innovative ways to successfully contain and clarify tailings and recycle tailings water. This includes use of sand bags, setting up silt fences and planting on the silt fences. Some recommendations of the 2008 manual have been used at Gloria Creek in Potaro Mining District#2 and have caused a reduction of pollution levels by approximately 40%.

Solid Waste Management and Sanitation: Lack of solid waste management and inadequate sanitary facilities exposes miners and visitors to an unhealthy camp environment. Many camps do not have sanitation facilities or solid waste disposal pits. There is need for community mass education to allow all the population to understand the dangers of poor sanitation. Many young persons leave the cities and villages to get quick money in the mines. They rarely stay beyond a few months. One assumes that if sanitary conditions were better, family members could visit camps thus causing greater stability of the work force. Better waste management could also release space for games and recreation.

On June 30, 2010 W. T. Dalgety wrote the Hon. Prime Minister of Guyana Samuel A. Hinds who has responsibility for GGMC and the mining sector. The letter describes conditions concerning water and sanitation observed at two miners‟ camps in Groete River on the 22nd June 2010. Dalgety wrote, “I walked around two camps. The water for both locations was pumped from Groete River. The sanitary conditions at the camps were unacceptable. Toilet facilities are non-existent. Garbage is strewn in the surrounding space. This space is adequate for recreation after work if solid waste management is employed. Dalgety noted that there was an abundance of water but little was directed towards recreation and sanitation. We must insist and regulate mining camps to be fit for grandmothers in the march of progress”.

The letter also went on to state that “it should not cost a licence holder G$100,000.00 (US$500.00) to install a modern toilet that can be moved from one camp site to another” and it ended by stating that “many licence holders visit their properties but consider it unimportant to improve conditions under which their male miners work. It is our concern in the peopling of our country”[9].

The Prime Minister fully supported the thrust of the letter. His response was that “camps can and ought to be improved – visits of family members of workers in the camps should be facilitated”. He was “100% in agreement” that modern toilets should be installed at camp sites to accommodate significant females. Improved sanitation in mine camps was addressed by a GENCAPD draft proposal in early 2010. The design of GENCAPD toilets for adaptation by miners (Figure 4) was recently posted at main mining locations. These toilets could be erected at an estimated cost of about G$125,000.00 (US$625.00) [10].

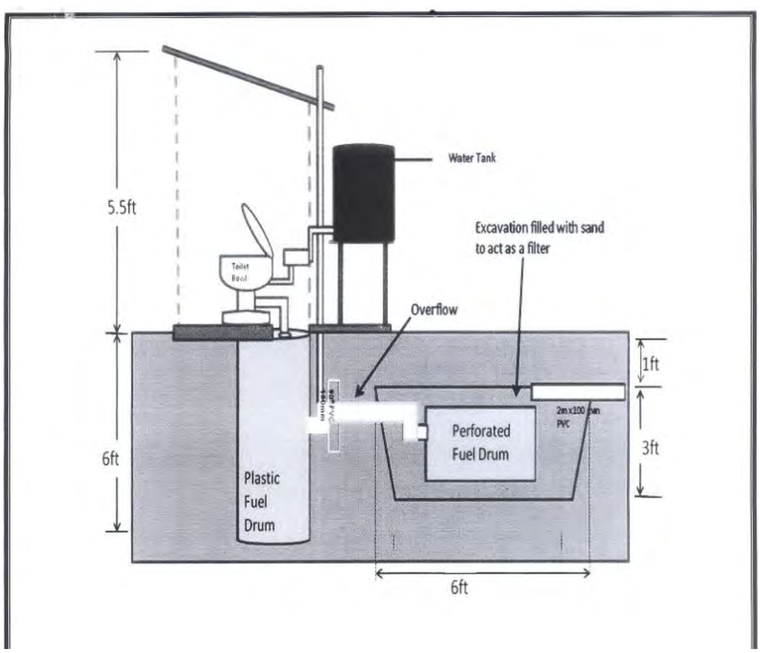

Figure 4, Flush Toilet Design for Miners

Process Technology: Improvements in process technology will help to reduce waste and the level of contaminants entering the environment. The Shaking Table fed by a Vibrating Screen process to optimize gold recovery without mercury use is being demonstrated in mining districts throughout Guyana. Other equipment beyond the sluice box used to increase recovery of gold includes the pinched sluice (called "warrior" locally), centrifugal concentrators, and jigs. Although these technologies are in use by some miners they are not in widespread use. A closed retort system should be the norm. In this system mercury vapour is captured during the final processing stage and recycled. This ensures that mercury is not being released to the environment.

Reclamation: GGMC recognises that successful reclamation of mined out areas provides the best legacy the gold mining industry can leave for future generations of Guyanese. Reclamation was successfully demonstrated at some mined out areas where pastures for small ruminants, lime, acacia and fast growing Paulownia trees were established. The Paulownia could be harvested for timber, energy, paper pulp and forage as a second career for ex-miners. Reforestation of mined out sites is consistent with Guyana‟s Low Carbon Development Strategy (LCDS) as it increases standing forest while rehabilitating sites disturbed by mining. GGMC has a plant nursery at Mahdia, Potaro mining district #2, providing seedlings for mine site reclamation.

GUIANA and WEST AFRICAN MINERS COLLABORATION

Written in the GGMC „The Mining Sector In Guyana 2010‟ report is the following: "Guyana lies within the Amazonian Craton. The Amazonian Craton is subdivided into two geographic shields, the Guiana Shield in the north (in which Guyana is situated) and the Central Brazil (Guapore) Shield in the south. The Amazon Craton shows striking similarities to the West African Shield. Both connected and formed part of a larger continent, prior to the opening of the Atlantic during the Mesozoic period".

With this similar geology, figure 8 shows a number of gold mines and gold occurrences in Venezuela, Guyana, Surinam, French Guiana, Ghana, Guinea, Mali, Burkino Faso, Ivory Coast, Liberia, and Nigeria [11]. Small and Medium Scale miners of all these countries should associate and take advantage of their endowment. The heritage of courage and motive to search for gold needs accelerated action to be more affective and beneficial to the African Diasporas in gold mining. A congress jointly organised by Guyana and West African mining associations should be held as soon as possible to address this goal.

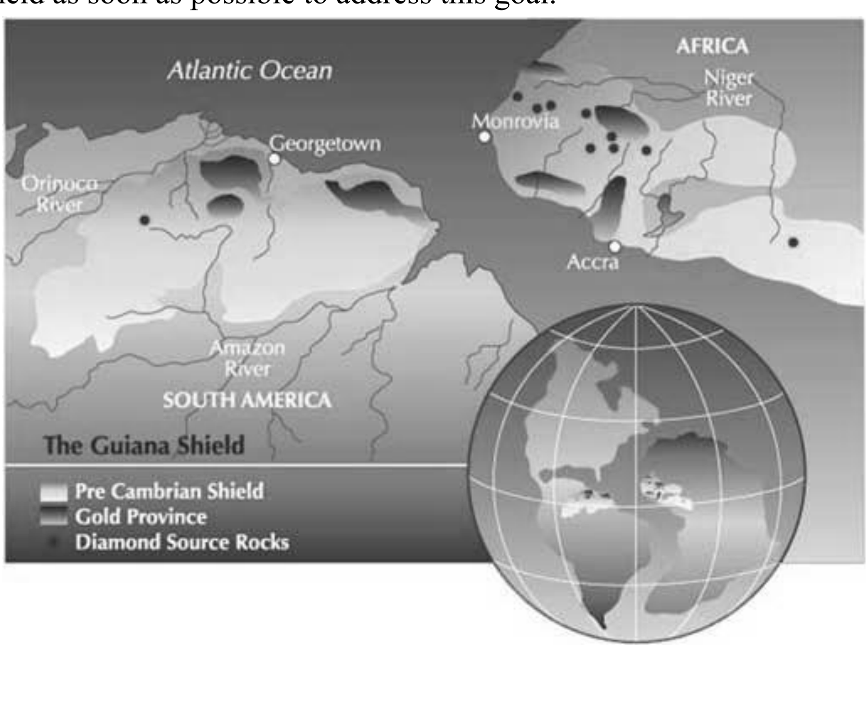

Figure 8, Guyana shield and West African craton

CONCLUSIONS and RECOMMENDATIONS

1. GGMC is moving generally in the right direction in terms of tailings management; solid waste management and sanitation; improved processing and retorting; and reclamation. Academically capable Guyanese should perceive a career as miners. Two-thirds of gold mining is done by persons with little secondary education and technical training. This needs to change. A lot more has to be done in the education of miners. In addition to mining manuals other means should be made to educate miners in the basics of tailings management, solid waste management and sanitation, processing including retorting and reclamation.
2. A lot more has to be done with respect to collaboration among West African gold miners and African gold miners in the Diasporas – in Guiana and Guyana particularly.
3. A West Africans in the Western Hemisphere conference in mines management should be held as soon as possible.

REFERENCES

[1] GGMC, The Mining Sector in Guyana, p4, 2010
[2] Kantharaja D C, Gold (Au) in Guyana, p1, 2006
[3] Arero H, Gold and Silver links, p1, (unpublished)
[4] GGMC, Checklist for GGMC Determination of Forest Clearing by Mining for MRV/LCDS, Education and Awareness and Technical Assistance to Miners, Environmental Monitoring, Compliance Enforcement, and Geological Mapping and Exploration Campaign, February to March 2010, p8, 2010
[5] Johil Commercial & Transport Agency, 6" Gold Quotation, 2010
[6] Livan K, Environmental Management in Small-Scale Mining, Swiss Agency for Development and Cooperation, 7, 267-269, 2004
[7] GGMC, Almanac 2010
[8] Hutson P, Miners Manuel: A Guide to Management and Self Monitoring, 2008
[9] Dalgety W T, Letter to Prime Minister of Guyana, 2010
[10] Hutson P, Sanitation in Mining Camps, GENCAPD Mining & communities, p4, 2010
[11] Guyana Goldfields Inc, Aurora Resource & Geology, www.guygold.com, 2-3, 2010

WASTEWATER MINIMISATION IN THE PRODUCTION OF KENKEY (A TRADITIONAL GHANAIAN CORN MEAL PRODUCT)

[1]N.D.K. Asante. [2]A Amponsah, [1]N.K. Owusu-Brafi
[2]B. Amoa, and [2]F.K. Saalia

[1]Food Process Engineering Department, Faculty of Engineering Sciences, University of Ghana, Legon, Accra, GHANA, Email: ndasante@ug.edu.gh ; [2]Department of Nutrition and Food Science, University of Ghana, PMB, Legon, Accra, GHANA

Key words: Water Minimisation, Reuse, Recycle, Waste Management, Corn Steeping

Abstract

Kenkey is a traditional Ghanaian corn meal product produced on a micro to small scale in a process that includes corn steeping, with the spent steep water generally being discarded without treatment. The increasing number and scale of Kenkey producers, implies that the environmental impact of this wastewater discharge cannot be ignored. There are however major economic and technical obstacles to the traditional solutions of either requiring the Kenkey producer to treat the waste, or central collection and wastewater treatment. The reuse of spent steep water in Kenkey production was investigated as an alternative approach to handling this wastewater problem. Potential modifications to the traditional steeping process were considered, including the addition of SO_2 *to the steep water. Samples of products from reuse were subjected to physical, sensory and microbiological analysis to determine the impact of the reuse. Results obtained indicate that under certain conditions, spent steep water can be reused in the steeping process to yield Kenkey that is acceptable to consumers and not significantly different from traditional Kenkey.*

INTRODUCTION

Kenkey is a traditional corn meal product native to the coastal region of Ghana including the capital, Accra. It is produced primarily on a micro to small scale in a process that includes corn steeping, with the spent steep water generally being discarded without treatment. This practice of discharging waste without treatment is common to almost all traditional food production in Ghana, with varying severity of impact on the environment.

With the dramatic increase in the population of Accra over the last decade, the number and scale of artisanal production is reaching a point where the pollution they create is no longer insignificant. There are however major economic and technical obstacles to the classic solutions of either requiring the producers to treat their waste prior to discharge, or to the municipal authorities collecting the wastewater and treating it centrally. Municipal authorities are focussed on dealing with the growing crisis related to the collection, treatment and disposal of solid domestic waste, and Kenkey producers do not generally have the financial or technical foundation to treat their waste prior to discharge. Thus, whilst central treatment of this liquid waste may be the long term solution, it is not a viable short or medium term solution.

As an alternative to the classic solutions to waste management, this research sought to determine the extent to which principles of water reuse and recycle could be employed to significantly reduce or even eliminate the wastewater produced. The objective of the study was therefore to identify modifications of the the Kenkey production process that would reduce or eliminate the production of wastewater whilst maintaining a product acceptable to consumers, without compromising on product safety.

PROCESS ANALYSIS

Sources and Sinks

The first stage of the study was to identify opportunities for water reuse and recycle, as a means of reducing water usage and wastewater generation. Water Pinch techniques [9] were adapted for this task to identify the water using steps (i.e. water sinks) and water generating or rejecting steps (i.e. water sources) of the process. The process for Kenkey production [4] is illustrated in Figure 1, showing where water is used and discarded within the process.

A key step in water pinch analysis is to determine the quality constraints for water usage within the process, as well as identify the quality characteristics of all the water that is discarded within the process. This is used to identify and eliminate infeasible reuse options, reducing the number of options for further consideration. The Kenkey process does not however have defined quality constraint for water usage, and as such all options had to be considered.

The sources and sinks identified in Kenkey production are shown in Table 1.

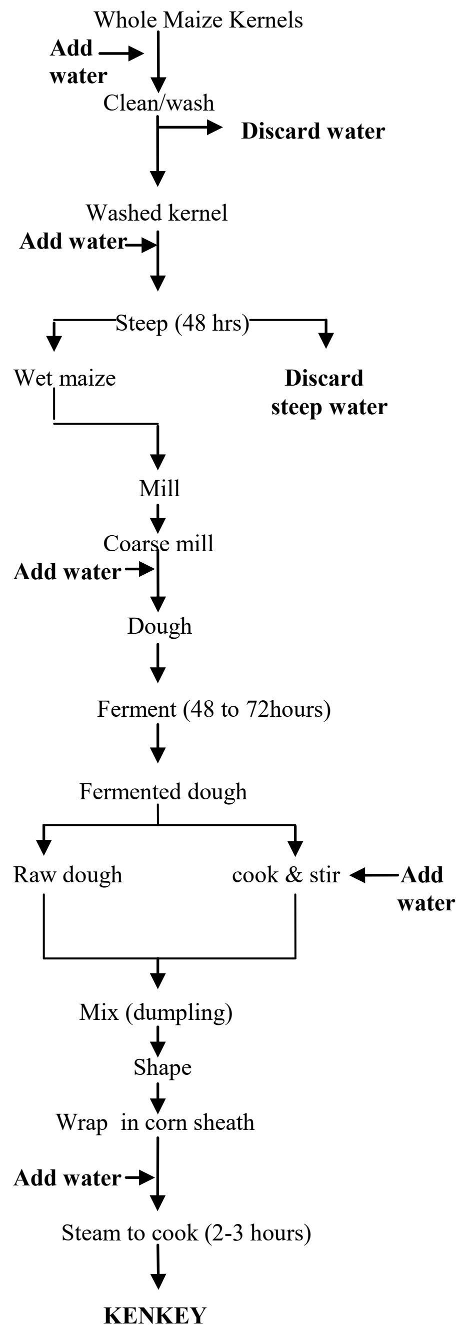

Figure 1: The Kenkey Production Process

Sinks	Sources
Corn washing	Wash water

Corn Steeping	Spent steep water
Dough making	
Cooking dough portion (aflata)	
Kenkey cooking (steaming)	

Table 1: Water Sources and Sinks in the Kenkey Production Process

Although there is some water left over from the cooking process, this water can be considered to be a by-product of the Kenkey production process and was not therefore considered for reuse.

Identification and Screening of Reuse Options

The initial list of reuse options is generated by matching all sources with all sinks, as shown in Table 2, followed by screening to eliminate infeasible or undesirable options.

Source of water	Sink (reuse target)
Wash Water	Corn washing
	Corn Steeping
	Dough making
	Cooking dough portion (aflata preparation)
	Kenkey cooking (steaming)
Spent Steep Water	Corn washing
	Corn Steeping
	Dough making
	Cooking dough portion (aflata preparation)
	Kenkey cooking (steaming)

Table 2: Reuse and recycle possibilities in the Kenkey production process

The wash water was considered unfit for reuse for any purpose other than washing, because by definition it would contain dirt and other substances deemed to be undesirable in the final product. The reuse of the wash water in any subsequent processing steps would re-introduce this dirt into the product. Elimination of the wash water from consideration leaves the reuse options listed in Table 3.

Source of water	Sink (reuse target)
Wash Water	Corn washing
Spent Steep Water	Corn washing
	Corn Steeping
	Dough making
	Cooking dough portion (aflata preparation)
	Kenkey cooking (steaming)

Table 3: Screened reuse and recycle possibilities

EVALUATION OF STEEPWATER REUSE OPTIONS

The screened opportunities for reuse and recycle thus identified were subjected to further analysis to determine their viability. As this is a food product, a number of laboratory experiments were required to determine the impact of the proposed reuse options on both the final Kenkey product as well as some intermediate products in terms of physical, chemical, microbiological and sensory properties. Due to the large number of experiments required, the only options covered in this paper are the reuse of the spent steep water for corn steeping and for dough making. These steps in the process have been demonstrated by previous researchers [5,6,7] to have a significant impact on the quality and properties of the resulting product.

Evaluation Procedure

100g of washed maize was steeped at a constant steeping time of 24 hours. The spent steep water from this first batch of corn was reused to steep two further batches of 100g of washed maize, so as to produce three types of steeped grain as follows:

Fresh – **corn steeped with fresh water.**
First generation – **corn steeped with steep water from fresh sample.**
Second generation – **corn steeped with steep water from first generation sample**

An additional variable included was the use of 0.2% SO_2 in the steep water as a means of inhibiting the growth of undesirable microorganisms – a practice long employed for steeping in the corn wet-milling industry [3].

Each of the steeped corn samples was then milled and made into dough, using both fresh water (the normal process), and spent steep water from a batch of corn steeped with fresh water. The dough was then left to ferment for 24 and 48 hours.

Various properties of the resulting fermented dough were measured, including pH, total titrable acidity and pasting characteristics, to determine if there was any discernible impact from the reuse of steep water. Finally, each of the 24 hour fermented dough samples was mixed and stir cooked into aflata using fresh water, and then used in the preparation of Kenkey for consumer acceptability tests. To reduce variability in the product, an experienced commercial Kenkey processor prepared the aflata and Kenkey after the dough had been produced in the laboratory.

Sensory analysis was conducted using untrained consumers randomly recruited from the University of Ghana campus. Criteria for recruitment were that panellists were regular consumers of Kenkey and were familiar with the characteristics of Kenkey.

Results and discussion

A detailed presentation and discussion of the results of the experiments is presented elsewhere [1], and only the highlights are provided here.

Impact on Steep Water

The water discharged from the steeping of unwashed grain was measured to have a BOD^5 ranging between 300 and 340 mg/l, which is significantly above the Ghana Environmental Protective Agency discharge limit of 50mg/l.

It was observed that with the addition of SO_2, the steep water was cleaner in appearance compared to steep water without SO_2 which appeared cloudy after second generation steeping. Steep water without SO_2 tended to develop a foul odour during and after second generation steeping, however with the addition SO_2, this foul odour development was significantly reduced. This indicates that water without SO_2 can be reused for steeping other batches of maize only up to first generation steeping. Based on this finding, second generation steep water without SO_2 was eliminated from further consideration, leaving a total of ten different process options (including the control consisting of the traditional Kenkey product) to be analysed.

Effects on corn dough quality

The pH and titratable acidity of dough prepared from each of the water reuse treatments followed the same trend as the control:- pH decreased with increasing fermentation time, with a corresponding increase in titratable acidity for all the samples. These results (especially those from corn dough prepared from steep water containing SO_2) indicate that the fermentation proceeded as in normal corn dough, and that SO_2 had little or no adverse effect on the desired activities of the microbial flora of the dough.

The effect of the different dough treatments on pasting characteristics (i.e. pasting temperature, peak viscosity and setback viscosity) were also determined to provide a measure of the performance of the dough [8]. Pasting temperatures did not vary significantly with the steeping treatment or the type of water used in the preparation of the dough. Pasting temperatures observed ranged between 79°C and 83°C, with the control sample having a pasting temperature of about 80°C. Peak viscosity was not significantly affected by water reuse, but rather by the presence of $SO_{2.}$ Peak and setback viscosities increased whenever steeping of the maize kernels was done in the presence of SO_2. This may be due to the action of SO_2 in releasing the starch granules during the steeping process [2]. Peak and setback viscosities however decreased when steep water without SO_2 was used in the preparation of dough. This could be due to the activities of microorganisms that were already present in the steep water added during the preparation of the dough.

The results above demonstrate that the use of steep water in dough preparation does not adversely affect the quality of the dough in terms of pH, titratable acidity and pasting characteristics, provided SO_2 is added to the steep water. Without SO_2 addition however, reuse lowers peak and setback viscosities.

Effect on Kenkey Product

The level of preference in terms of taste, smell, colour, texture and overall acceptability of Kenkey produced from each of the 24-hour fermented corn dough as well as traditionally prepared Kenkey was analysed. A selection of the rank sums indicating the degree of preference are shown in Table 4.

	Sample	Sum of Ranks	Order of Ranks
1	Control (traditional process)	116.7	1st

2	First Generation Steepwater	121.8	2nd
3	First Generation Steepwater + SO2	129.0	3rd
4	Fresh with steepwater reuse for dough	152.5	4th
5	Second Generation +SO2 and reuse for dough	221.1	10th

Table 4: Selection of Friedman sensory ranking scores for overall preference of Kenkey samples

With respect to taste, samples 2, 3 and 4 in Table 2 were not significantly different from the control (sample 1 – traditional process). Texture, was the attribute that varied the least among the samples and this implies that the different treatments given to the maize and dough did not significantly influence the texture of the resulting product.

Smell, colour and overall acceptability of the different Kenkey samples were however significantly affected by the treatments given to the maize and dough. This suggests that the primary concern in steepwater reuse would be the development of undesirable odour or aroma in the Kenkey product. It is important to note however that the development of such undesirable odour is a significant risk in the preparation of the traditional Kenkey product itself.

CONCLUSIONS

The feasibility of reuse of spent steep water for steeping and for dough preparation in Kenkey production has been demonstrated. The primary obstacle to the reuse of steep water appears to come from the foul odour that develops with time due to activity of bacteria in the steep water. The development of foul odour can however be mitigated by the introduction of SO_2 in the water used for steeping, and this does not prevent the activity of the lactic acid bacteria required for subsequent fermentation.90

The presence of SO_2 during steeping and the reuse of steep water for steeping other batches of maize did not affect the quality of dough and the consumer acceptability of Kenkey produced. Kenkey prepared using dough made from maize that had been steeped in reused steep water had sensory attributes not significantly different from traditionally produced Kenkey. The use of steep water in dough preparation for Kenkey was however not acceptable to consumers. Results obtained from sensory analysis indicate that spent steepwater can be reused for steeping a second batch of corn with or without the addition of SO_2 to the water, and the resulting Kenkey produced is acceptable to consumers.

This study demonstrates a potential approach to mitigating the environmental impact of traditional artisanal food production in developing countries, until suitable municipal waste management is effectively implemented.

ACKNOWLEDGEMENTS

This research work was funded by a grant from the University of Ghana Research Fund, whose support is gratefully acknowledged.

REFERENCES

[1] Amponsah, A. (2010). The Ga *kenkey* production process- investigating opportunities for water reuse and identification of sources of product quality variability. M. Phil Thesis, Department of Nutrition and Food Science, University of Ghana, Legon.

[2] Eckhoff, S. R. and Tso, C. C. (1991). Wet milling of corn using gaseous sulfur dioxide addition before steeping and the addition of lactic acid on steeping. *Cereal Chemistry* 68:248-251.

[3] Greenfield, R. E., Cornell, G. N., and Hatfield, W. D. (1947). Cornstarch processes. *Ind. Eng. Chem*., 39, 583-588.

[4] Halm, M., Amoa-Awua, W. & Jakobsen, M., (1996). Kenkey, an African fermented maize product. In: *Handbook on fermented foods and beverages science and technology* (eds) Hui, Y.H., Toldra, F., Nip, W.K. and Meunier-Goddik L. Marcel Dekker, New York, pp 799-818.

[5] Nche, P. F., Odamtten, G. T., Nout, M. J. R. & Rombouts, F.M. (1994). Dry milling and accelerated fermentation of maize for industrial production of Kenkey, a Ghanaian cereal food. *J. Cereal Sci*, 20, 291-8.

[6] Nche, P. F., Odamtten, G. T., Nout, M. J. R. & Rombouts, F.M. (1996). Soaking determines the quality of aflata for kenkey production. *J. Cereal Sci*., 24, 291-297

[7] Nout, M.J.R., Kok, B., Vela, E., Nche, P.F., Rombouts, F.M. (1996). Acceleration of the fermentation of kenkey, an indigenous fermented maize food of Ghana, *Food Research International*, Vol. 28, No. 6, 599-604.

[8] Shuey, W.C. and Tipples, K.H. (1982). The amylograph handbook. 2nd edition. The American Association of Cereal Chemists, St. Paul, Minnesota, USA. 1 -31.

[9] Wang, Y.P. and Smith, R. (1994), Wastewater Minimisation. *Chemical Engineering Science*, 49: 981-1006.