Appropriate Technologies for Environmental Protection in the Developing World

Ernest K. Yanful
Editor

Appropriate Technologies for Environmental Protection in the Developing World

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Cover photos (from top left):

Photo 1: Regular manual street sweeping in Kumasi, Ghana, helps maintain a clean environment whilst creating employment opportunities for the urban poor: June 2008. Courtesy of Anthony Mensah, Kumasi Metropolitan Assembly

Photo 2: Preparing the base course for surface dressing of access road to Kumasi Sanitary Landfill site: July 2003. Courtesy of Anthony Mensah, Kumasi Metropolitan Assembly

Photo 3: Small mud house (kitchen) constructed with bamboo frames at Enyan Abaasa, Central Region Ghana. Courtesy of Ernest K. Yanful

Photo 4: Foreground: Kumasi Sanitary Landfill & Septage Treatment Facility. Courtesy of Anthony Mensah, Kumasi Metropolitan Assembly

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Preface

This book is the first edited compilation of selected, refereed papers submitted to ERTEP 2007. The selected papers either dealt with technologies or scientific work and policy findings that address specific environmental problems affecting humanity in general, but more specifically, people and ecosystems in developing countries. It was not necessary for the work to have been done in a developing country, but the findings and results must be appropriate or applicable to a developing country setting. It is acknowledged that environmental research, technology applications and policy implementation have been demonstrated to improve environmental sustainability and protection in several developed economies. The main argument of the book is that similar gains can be achieved in developing economies and economies in transition.

The book is organized into six chapters along some of the key themes discussed at the conference: Environmental Health Management, Sustainable Energy and Fuel, Water Treatment, Purification and Protection, Mining and Environment, Soil Stabilization, and Environmental Monitoring. It is hoped that the contents of the book will provide an insight into some of the environmental and health management challenges confronting the developing world and the steps being taken to address them.

Acknowledgements

The Editor wishes to thank the authors of the papers for their contribution to this volume. Publications coordinator, Robyn Gaebel, did an excellent job handling the selected manuscripts and communicating with the authors. Alex Dolson, Shahenda Abou-Aly, Cindy Quintus and Erin Cullen provided editorial assistance in the compilation of papers for the original conference proceedings. Funding for the conference was provided by the Geotechnical Research Centre and Research Western at The University of Western Ontario, Duke University Pratt School of Engineering, the Canadian International Development Agency, Ministry of Local Government, Rural Development and Environment, Ghana, Goldfields Ghana Limited, Newmont Ghana Gold, AngloGold Ashanti, Tema Oil Refinery, Shell Ghana Limited, Volta River Authority, Ghana, Zoomlion Environmental Limited, New Times Corporation, Graphic Communications Group Limited and Ghana Telecom.

Introduction

Global industrialization and trade affecting developing countries have occasioned increasing human and economic activities that tend to impact negatively on the environment. Such impacts have created huge environmental problems of air, water and land pollution that confront governments and require mitigating solutions. Recent world summits have highlighted the need to develop environmental technologies and policies to protect fragile ecosystems. The purpose of the First International Conference on Environmental Research, Technology and Policy, ERTEP 2007, was to discuss grass-root environmental issues, assess efforts by government machinery and identify what communities and corporate entities can do as a social responsibility to mainstream and maintain environmental protection and integrity for sustainable development. The three-day conference attracted some 250 people delegates from 18 countries. Invited plenary lectures on policy were presented by high ranking officials from the Ghana Government, including the sector Ministers for Local Government, Rural Development and Environment (Honorable Stephen Asamoah-Boateng), Lands, Forestry and Mines (Honorable Professor Dominic Fobih), and Women and Children's Affairs (Honorable Hajia Alima Mahama). Osagyefuo Amoatia Ofori Panin, the Okyenhene (Ghana) opened the conference, while Honorable Joseph Henry Mensah, Senior Ghana Government Minister delivered a plenary address. Other plenary and keynote speakers included Dr. Ulf Jaeckel, Federal Ministry for the Environment, Berlin, Germany, Ms. Joyce Aryee, Ghana Chamber of Mines, Mr. Charles Darku, Volta River Authority, Ghana, Mr. Lars-Ake Lindahl of the Swedish Mining Association, Dr. Wanda Günther Risso, University of Sao Paulo, Brazil, and Mr. Peter Steblin, City Engineer, City of London, Professor George Nakhla, University of Western Ontario, Canada, and Dr. Clement Dorm-Adzobu, and Mr. Philip Acquah, Ghana. The plenary lectures were followed each day by technical breakout sessions during which more than 100 papers were presented under the seven themes of the conference: Environment, Health and Safety, Oil and Gas Extraction and Environment, Forestry and Environment, Mining and Environment, State-of-the-Art Technologies for Environmental Performance and Protection, Integration of Gender in Environmental Management, Environmental Monitoring Institutions and Policy Development, and Sustainability, Corporate Investment and Social Responsibility.

Nearly all technical papers presented at ERTEP 2007 were reviewed by a theme of international referees selected on the basis of their expertise in the subject area. Each paper was reviewed by at least two referees and written comments were sent to authors for the preparation of revised papers. Following the conference, the Editor of the current volume and ERTEP 2007 Conference Chair, Professor Ernest Yanful, and three editorial assistants, Robyn Gaebel, Cindy Quintus and Alex Dolson selected a number of refereed papers dealing with technologies and policy interventions appropriate for use or application in the developing world for publication. Authors of the selected were informed of the process and additional revisions were requested by the Editorial Team to produce this final volume.

Editor
Professor Ernest K. Yanful
Editorial Assistants
Robyn Gaebel, Cindy Quintus, Alex Dolson
and Long Vu

Contents

A Comparative Case Study of Detection of Radiation in Vegetable Leaves in a Coastal Oil Producing and Hinterland Non-oil Producing Regions in Akwa Ibom State

G.T. Akpabio and B.E. Bassey

Abstract The purpose of this work is to determine how safe vegetable leaves are in an oil producing area, using a case study of the Akwa Ibom State. Radioactive radiation levels were detected for five samples of vegetable leaves namely Waterleaf (Talinum triangulare), Bitter leaf (Veronia amygdalina), Fluted pumpkin (telfairia occidentalis), Editan, (Lasientera Africana) and Afang (Gnetum africanum). The vegetable leaves were collected form Uyo (hinterland region) and Ibeno (coastal region) in Akwa Ibom. Radioactivity levels in each of these samples were determined. In Uyo, waterleaf had the least radioactive level of 0.00079 Bq/g while Editan recorded the highest level of 0.0019 Bq/g for Ibeno, its Fluted pumpkin showed the least of 0.0037 Bq/g whereas waterleaf records the highest radioactive level 0.0070 Bq/g. The higher radioactive level observed in Ibeno is attributed to the presence of radioactive materials in the environment due to oil drilling activities in the area.

Keywords Radioactivity · radiation · vegetable leaves · NORM

1 Introduction

Radiation is a form of energy that originates from a source and travels through some material or through space. The term radiation in its wavelike form emits particles, such as electrons, neutrons, or alpha particles as well as electromagnetic radiations. Nuclei that are not stable are radioactive (Tippler 1991). Radioactivity can be dangerous to human health. Naturally occurring radioactive materials (NORM), produced along with oil and gas production, are often concentrated at some points in the hydrocarbon production process. Concentrations of NORM are

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found in oil and gas production equipment and waste. The radioactive component is the major environmental concern, especially in places like Akwa Ibom State and other oil producing regions.

Many processes occur in a leaf, but the distinctive and most important is the process of food manufacture. Green plants posses the ability to manufacture food from raw material derived from the soil and air. It is on these activities that not only the life of plants but also the life of all animals, including man depends (Wilson et. al. 1971). All leaves are metabolic factories equipped with photosynthetic cells, but that vary enormously in size, shape and texture (Starr and Targgart 1995). Vegetables leaves are plant or part of plant (leaves) that is eaten as food (Hornby 2001).

There are a number of devices that can be used to detect the particles and photons emitted when a radioactive nucleus decays; such devices detect the ionization that these particles and photon cause as they pass through matter (Cutnell and Johnson 1998). The presence of radioactive substance is easily detected with a Geiger Muller (GM) counter, based on the ionization produced by the radioactive emanations, (Eno 1998). One of the most common radiation detectors is the Geiger counter. These radiation detectors are based upon the ionization or excitation of atoms by the passage of energetic particles through matter (Wilson and Buffer 2000). The GM counter is non-energy dissipative, hence effectively useful for environmental radiation measurements, (Sigalo and Briggs-Kamara 2004).

The rate at which radioactive materials disintegrate or decay is almost independent of all other physical and chemical conditions (Akpabio and Ituen 2006). The activity of a radioactive sample can be expressed in terms of the rate of decay, that is, the number of disintegration per second in the sample (Howill ands Sylvester 1976). Unstable nuclei are radioactive and decay by emitting α particles (4He nuclei), β particles (electrons or protons), or γ rays (photons) (Tipler 1991). Radioactivity, or the emission of α- or β-particles and γ rays, is due to the disintegrating nuclei of atoms. All radioactivities are statistical in nature and follow an exponential decay law, Equation (4).

The number of atoms disintegrating per seconds, dN/dt, is directly proportional to the number of atoms, N, present at the instant (Nelkon and Parker 1977). Hence;

$$\frac{dN}{dt} = -\lambda N \tag{1}$$

Where λ is a constant characteristic of the atom concerned called the radioactivity decay constant. Thus, if N_o is the number of radioactive atoms present at a time t = 0, and N is the number at the end of a time t is

$$N = N_o e^{-\lambda t} \tag{2}$$

The time it takes for the number of nuclei or the decay rate to decrease by half is called the half-life $T_{1/2}$. Equation (2) shows that:

$$\frac{N_o}{2} N_o e^{-\overline{\lambda t}} \tag{3}$$

Therefore,

$$T_{1/2} \frac{1}{\lambda} \text{In } 2 \; 2 \frac{0.693}{\lambda} - \tag{4}$$

$$T_{1/2} \frac{0.693}{\lambda} \tag{5}$$

1.1 Material and Method

Waterleaf, Bitter leaf, Fluted pumpkin leaf, Afang leaf (Gnetum africanum), Editan leaf (Lasienthera africana) were each collected form Ibeno (Oil producing area) and Uyo (non-oil producing area) of Akwa Ibom State. The fresh samples of the vegetables were carefully plucked and mesh using the pestle and mortar. The meshed samples were now transferred carefully into the beaker and were placed directly under the Geiger–Muller tube. The experiment was repeated in each case in order to determine the average value and the distance between the Geiger–Muller tube and the beaker was kept constant throughout the experiment. Reports of environmental monitoring of radiation levels in which Geiger–Muller Counters have been used include Sigalo and Briggs-Kamara (2004) among others.

2 Results and Discussion

Results of the radiation levels in each of the vegetable samples for the two locations are presented in Tables 1 and 2.

At Ibeno (Table 1), waterleaf has the highest radiation level of 0.0070 Bq/g and Afang leaf the minimum of 0.0034 Bq/g. Table 2 shows that in Uyo, Editan had the highest level of radioactivity, followed by bitter leaf and the least in waterleaf. The histogram representing radioactivity in vegetables as shown in Fig. 2, give the comparison between Ibeno and Uyo. Ibeno generally has a higher level of radioactivity in the vegetable leaves when compared to Uyo. This is of great concern because according to Mgbenu et al. (1995), the exposure of human being to nuclear radiation is very harmful. Its damage to the human body depends on the absorbed dose, the exposure rate and the part of the body exposed. If the permissible level is greatly exceeded, the individual can suffer effects, which may be (a) somatic and (b) Genetic (Mgbenu et al. 1995). Similar results were found for roots of plants within the same environment and were obtained by Akapbio and Ituen (2006). Oil drilling sites and production facilities have many radioactive materials associated with them.

Table 1 Experimental results for samples obtained from Ibeno LGA

Samples	Mass	Background count for 10 min	Background + sample count for 10 min	Sample count for 10 min	Corrected count for 1 s	Counts per gram (Bq/g)
Water leaf	6.029	109.0	134.0	25.0	0.042	0.0070
Bitter leaf	9.093	119.3	142.7	23.4	0.039	0.0039
Pumpkin leaf	9.0881	118.0	135.0	17.3	0.029	0.0037
Editan leaf (Lasienther africanan)	5.644	112.3	131.3	19.0	0.032	0.0060
Afang leaf (Gnetum africanum)	5.402	128.3	139.7	11.4	0.019	0.0034

Table 2 Experimental results for samples obtained from Uyo LGA

Samples	Mass (g)	Background count for 10 min	Background + sample count for 10 min	Sample count for 10 min	Corrected count for 1 s	Counts per gram (Bq/g)
Water leaf	6.368	121.0	124.0	3.0	0.005	0.0079
Bitter leaf	9.462	107.7	120.0	9.0	0.015	0.0016
Pumpkin leaf	9.504	127.3	134.0	6.7	0.011	0.0012
Editan leaf (Lasienther africanan)	5.721	118.0	123.7	5.7	0.010	0.0019
Afang leaf (Gnetum africanum)	5.3922	117.3	121.3	4.0	0.019	0.0012

Drilling fluids used for onshore wells are primarily disposed of in reserve pit, while in many areas drilling fluids from offshore wells are primarily disposed of in reserve pit, while in many areas drilling fluids from offshore platforms have been dumped overboard (Reis 1996).

The offshore case is of importance to individuals in Akwa Ibom State because when oil is spilled on water, it spreads out over the water surface and moves with the wind and water current, (Reis 1996). This is the water that plants and animals in the area makes use of. Even though these levels of radioactivity are below the international permissible limit of 0.18 Bq/g, continuous accumulation over periods of time can be dangerous and the effects on humans have not been studied in depth.

3 Conclusion

The results show that the radioactivity levels in the vegetable in Ibeno (an oil producing area) is higher than at Uyo (a non-oil producing area).

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References

Akpabio, G. T. and Ituen, E. E. (2006) Comparative effect of radioactive radiation on roots in coastal and hinterland locations in Akwa Ibom State Nigeria. Nig. J. Phys. 18(1), 117–120.

Cutnell, T. D. and Johnson, K. W. (1998) Physics, 4th edition. Wiley, New York, pp. 976–977.

Eno, E. E. (1998) Electricity and Modern Physics. Footsteps, Port Harcourt, pp. 204–211.

Holwill, M. E. and Silvester N. R. (1976) Introduction to Biological Physics. Wiley, London, pp. 323–325.

Hornby A. S. (2001) Advanced Learner's Dictionary Oxford University Press. New York, p. 1325.

Mgbenu, A. E, Inyang, A. E., Agu, M. N., Osuwa, J. C. and Ebong, I. D. U. (1995) Modern Physics. Nigerian University Physics Series, Spectrum Books, Ibadan, pp. 188–207.

Nelkon, M. and Parker P. (1977) Advanced Level Physics, 4th edition. Heinemann, London, pp. 946–954.

Reis, J. C. (1996) Environmental Control in Petroleum Engineering. Gulf Publishing, Houston, TX, pp. 261–264.

Sigalo, F. B. and Briggs-kamara, M. A. (2004) Estimate of lonishing radiation levels within selected riverine communities of the Niger Delta. J. Nig. Environ. Soc. 2(2), 159–162.

Starr, C. and Targgart, R. (1998) Biology, 7th edition. Wardsworth Publishing, New York, p. 490.

Tipler, P. A. (1991) Physics for Scientist and Engineers, Vol. 2, 3rd edition, Worth Publishers. New York, pp. 1338–1361.

Wilson, C. L., Loomis, W. E., Steeves, T. A. and Holt, R. (1971) Botany, 5th edition. Winston, New York, p. 99.

Wilson, J. D. and Buffer, A. J. (2000) College Physics, 4th edition. Prentice Hall, Englewood Cliffs, NJ, p. 916.

Influence of Human Activities and Land Use on Heavy Metal Concentrations in Irrigated Vegetables in Ghana and Their Health Implications

E. Mensah, N. Kyei-Baffour, E. Ofori, and G. Obeng

Abstract Anthropogenic activities are major sources of heavy metal pollution which serve as major pathways for plant uptake of heavy metals like cadmium (Cd) and lead (Pb) to enter the human food chain from the soil and irrigation water. This study was conducted to investigate the levels of Cd, Pb, Zn, Fe, Ni and Cu concentrations in sampled vegetables (cabbage and carrots) from two major markets in Kumasi, a metropolis and two producing rural towns along the Accra – Kumasi road. Apart from Ni all other heavy metals in cabbage were far higher than the FAO/WHO permissible values of samples from both urban/peri-urban and rural communities. Cadmium content of the vegetables from the peri-urban communities were extremes (0.5–4.2 mg/kg) and were generally higher than produce from the rural communities with values between 1.6 and 1.9 mg/kg. However, cabbage from Asikam, a rural and mining community contained 2.9 mg/kg of Cd. Lead concentration levels in the sampled vegetables from the peri-urban communities ranged between 6–45 mg/kg whilst values from the rural communities were between 12 and 13 mg/kg. Cadmium and lead concentration levels in the sampled vegetables far exceeded FAO/WHO recommended maximum values of 0.3 and 0.2 mg/kg respectively with samples from urban/peri-urban communities registering higher values than those from the rural towns.

1 Introduction

Anthropogenic activities are major sources of heavy metal pollution which serve as major pathways for plant uptake of heavy metals like cadmium (Cd) and lead (Pb) to enter the human food chain from the soil and irrigation water. Lead leaf contents,

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for example, are very high in plants growing in urban and industrial areas (Maisto et al. 2004). Heavy metals found in agricultural soils originates from many sources including paints, gasoline additives, smelting and refining of Pb, pesticide production and Pb acid battery disposal (Eick et al. 1999; Paff and Bosilovich 1995), phosphate fertilizers, sewage sludge, wastewater for irrigation, waste from smelting sites and others (Ingwersen and Streck 2005). Cadmium is one of the most mobile and bioavailable heavy metals in soil and may cause human and ecotoxicological impacts even at low concentrations. There is considerable published information about the action of Cd^{2+} on plant growth and on physiological and biochemical processes. Harmful effects produced by Cd might be explained by its ability to inactivate enzymes possibly through reaction with the SH-groups of proteins (Fuhrer 1982). Detrimental effects are manifested in inhibition of photosynthesis and in oxidative stress leading to membrane damage (Prasad 1995).

Application of sewage sludge to agricultural land is a feasible alternative for reutilization residual resource of high nutrient and organic matter contents which represent a good fertilizer and/or soil conditioner for plant and soil (Logan et al. 1997; Wong 1996). Besides, sludge amendment could improve soil physical properties such as soil aeration, water holding capacity and aggregation (Logan and Harrison 1995) while the slightly alkaline property of the sludge buffers against the acidity of acidic soils.

Wastewater and sludge for irrigation or amendment of the agricultural land may lead to build higher concentrations in soils as a result of accumulation. The higher metal levels in soil may cause negative impact on crops, inhibiting the growth in one or other way. One of the most important factors is the pH of the soils. Alkaline pH of the soil would restrict the mobilization of the metal in soil matrix and consequently the metal uptake by crop plant would be controlled, reducing the risk of metal toxicity.

Heavy metals may enter the human body through inhalation of dust, direct ingestion of soil, and consumption of food plants grown in metal-contaminated soil (Sterrett et al. 1996) and/or irrigated with wastewater (Ingwersen and Streck 2005). Prolonged exposure to heavy metals (e.g. Cd, Cu, Pb, Ni and Zn) can cause deleterious health effects in humans (Reilly 1991). In children, Pb has been known to cause decreases in IQ scores, retardation of physical growth, hearing problems, impaired learning, as well as decreased attention and classroom performance. In individuals of all ages, Pb may cause anemia, kidney disease, brain damage, impaired function of the peripheral nervous system, high blood pressure, reproductive abnormalities, developmental defects, abnormal vitamin D metabolism, and in some situations death (Hrudey et al. 1995).

Heavy metal contamination can affect plant health and nutritional value of crops. High Cd concentrations can lead to toxicity symptoms like chlorosis and reduced growth of the leaves of crops. The severity of Cd phytotoxicity is found most evident from dry matter yield in both leaves and roots of crops (Michalska and Asp 2001). The extent of contamination to food crops is likely to increase with intensification of production systems, urbanisation and industrialisation but levels of food contamination are not regularly monitored or controlled. In Ghana vegetable consumption

has been on the increase as a result of changes in the eating habits of urban dwellers due to socio-economic changes with time. However, high percentages of vegetables consumed by urban dwellers are produced under wastewater irrigation. These exotic vegetables (cabbage, carrots, lettuce, spring onions, etc.) are produced mainly in the urban/peri-urban communities of Ghana. However, cabbage and carrots may be produced in some locations in a few rural communities. Location influences the type of inputs for vegetable production. Urban/peri-urban produced vegetables are irrigated with wastewater or urban streams that are receptacle of urban effluent, hand-dug wells and in very few situations treated water from the mains while the soils are conditioned and the nutrient levels are improved with sewage sludge. For vegetables produced in the rural communities source of irrigation water is mainly a stream or river and soil nutrient improvement and conditioning is by the application of inorganic fertiliser. The objective of this study was to determine the extent of human activities through the type of input used and land use on heavy metal concentration in irrigated vegetables in Ghana and probable health implications.

2 Materials and Methods

Vegetable samples were collected from two main vegetable markets in Kumasi (Asafo and "European") and two rural towns (Nsutam and Kibi) along the Accra–Kumasi highway between August and September, 2005, for the study. The collected samples were washed and rinsed with distilled water and chopped on a distilled water rinsed kitchen chop board using a washed and rinsed kitchen knife into pieces (of about 25 × 25 mm size for cabbage and 1 mm thickness for carrots). The chopped samples were sun-dried for about 8 h before subjecting them to oven drying for about 24 h at 70 °C. The oven dried samples were milled to pass a 2 mm sieve and were packaged in transparent plastic bags and sealed to prevent moisture ingression. 0.2 g of each plant sample was placed into a teflon beaker and 6 ml of concentrated nitric acid (HNO_3) was added and weighed. The beaker was assembled, placed in a rotor and tightened with torque wrench before placing the rotor in the chamber of an already programmed microwave digester for digestion. A 1-ml aliquot of digested sample was placed in a 15-ml centrifuge tube, diluted with 5 ml of deionized water, and analysed for Cd, Pb, Ni, Zn, Fe and Cu and lead with Agillent 7500 c ICP- MS.

3 Results

Figure 1 shows the concentrations of Cd, Pb, Ni, Zn, Fe, and Cu in vegetables from the various sites. Apart from Ni all the other heavy metals concentrations in cabbage were far higher than the FAO/WHO permissible values of samples from both urban/peri-urban and rural communities.

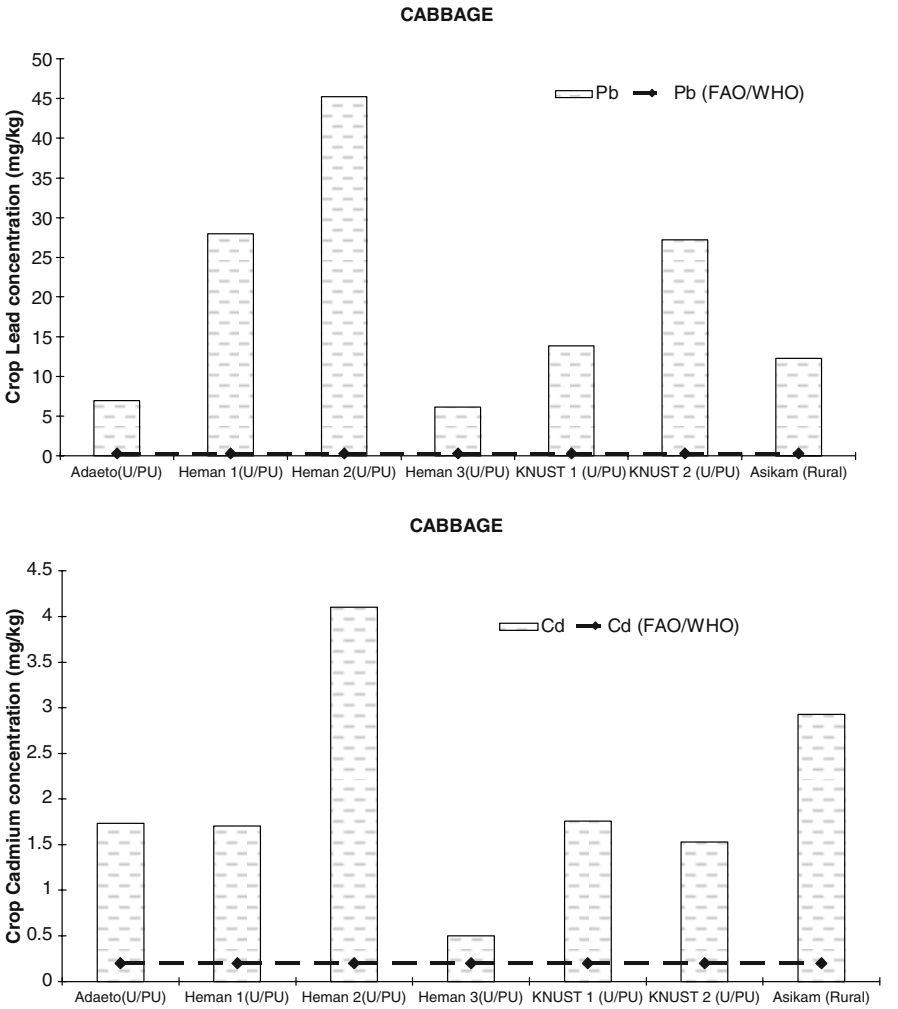

Fig. 1 Relationship between analysed heavy metals concentrations in cabbage samples from both rural and urban/peri-urban communities and permissible FAO/WHO permissible values/ guidelines

4 Discussion

The recommended concentration levels of the analysed heavy metals by FAO/WHO in vegetables is shown in Table 1.

Plant samples differed in levels of concentrations of heavy metals based on location. Most of the cabbage sampled had high levels of heavy metal concentration at Heman site 2, a rural community north of Kumasi. The high values of heavy metals concentrations of lettuce and cabbage may be due to the sources of irrigation water (streams) that receive

Table 1 FAO/WHO maximum permissible values of heavy metals in vegetables

Element	FAO/WHO maximum permissible values (mg/kg)
Cd	0.2
Pb	0.3
Ni	67.9
Fe	425.5
Cu	73.3
Zn	99.4

effluents and storm water from Kumasi "Magazine", the largest public sector garage in Africa. The values of Cd and Pb were similar to concentrations of cabbage grown and irrigated with water from streams close to a smelting factory in Addis Ababa, Ethiopia from a study carried out there (Itanna 2002). For the least plant heavy metal concentrations, there were variations for both plants and locations. Cabbage showed the highest concentrations of Cd and Pb which confirms results from a similar study by Petterson (1977). Most of the heavy metals concentration levels recorded were above maximum permitted concentrations by FAO/WHO. Human health implications of heavy metals are determined by accumulated concentration levels from ingestion through food. Food intake is related to body weight and age (Oliver et al. 1995). Also the quantity of vegetable intake is influenced by the level of development of a community in which the people live. In a developing country, it has been recommended that an average intake of carrots and cabbage per person in a day by a vegetarian is 113 g each and 21 g of lettuce (USEPA 2002). The WHO (1989) recommended daily intake of Cd per unit (kg) body weight of an adult is 1 μg. The maximum daily Cd intake, therefore, by a vegetarian of 50 kg weight will be 50 μg. A composite meal of carrots, cabbage and lettuce, for example, weighing 247 g for a 50 kg vegetarian in Ghana will be ingesting between 123.5 and 1,037 μg Cd which is about 2 to 21 fold of the recommended value. Sources of the heavy metals in the vegetables may vary and the sources may be fertilisers, poultry manure and water bodies used for production. The farmers use these inputs based on their availability and affordability. Because the Kumasi metropolis is choked with poultry farms majority of the farmers apply poultry manure to improve the soil. However, due to lack of extension services, the farmers tend to use knowledge from their counterparts in solving problems relating to soil fertility and plant diseases. This has been a major factor in the vegetable production sector in terms of environmental pollution.

5 Conclusion

The study showed that metal concentrations of the vegetables sampled were higher for those produced in the urban/peri-urban communities than those from the rural areas. It could be concluded that the vegetables on the Ghanaian market have high

heavy metals concentration levels above the maximum recommended by health authorities and this calls for a thorough investigation to track the source(s) of the metals and measures put in place to ameliorate or eliminate the menace. Soils being used for vegetable production locally are mainly sandy with low pH and organic matter content, favouring high uptake of heavy metals.

References

Eick, M.J., Peak, J.D., Brady, P.V., and Pesek, J.D., 1999. Kinetics of lead adsorption/desorption on goethite: Residence time effect. Soil Sci. 164:28–39.

Fuhrer, J., 1982. Ethylene biosynthesis and cadmium toxicity in leaf tissue of beans *Phaseolus vulgaris* L. Plant Physiol. 70:162–167.

Hrudey, S.E., Chen, W., and Rousseaux, C.G., 1995. Bioavailability in Environmental Risk Assessment. Boca Raton, FL: Lewis.

Ingwersen, J. and Streck, T., 2005. A regional-scale study on the crop uptake of cadmium from sandy soils: Measurement and modeling. J. Environ. Qual. 34:1026–1035.

Itanna, F., 2002. Metals in leafy vegetables grown in Addis Ababa and toxicological implications. Ethiop. J. Health Dev. 16(3):295–302.

Logan, T.J. and Harrison, B.J., 1995. Availability of heavy metals for Brassica Chinensis grown in an acidic loamy soil amended with domestic and industrial sewage sludge. J. Environ. Qual. 24:153–165.

Logan, T.J., Lindsay, B.J., Goins, L.E., and Ryan, J.A., 1997. Plant availability of heavy metals in a soil amended with a high dose of sewage sludge under drought conditions. J. Environ. Qual. 26:534–550.

Maisto,G., Alfani, A., Baldantoni, D., Marco, A.D., and Santo, A.V.D., 2004. Trace metals in the soil and in Quercus ilex L. leaves at anthropic and remote sites of the Campania Region of Italy. Geoderma 122:269–279.

Michalska, M. and Asp, H., 2001. Influence of lead and cadmium on growth, heavy metal uptake, and nutrient concentration of three lettuce cultivars grown in hydroponic culture. Commun. Soil Sci. Plant Anal. 32(3&4):571–583.

Oliver, D.P., Gartell, J.W., Tiller, K.G., Correll, R., Cozens, G.D., and Youngberg, B.L., 1995. Differential response of Australian wheat cultivars to cadmium concentration in wheat grain. Aust. J. Agric. Res. 46:873–886.

Paff, S.W. and Bosilovich, B.E., 1995. Use of Pb reclamation in secondary lead smelters for the remediation of lead contaminated sites. J. Hazard. Mater. 40:39–64.

Prasad, M., 1995. Cadmium toxicity and tolerance in vascular plants. Environ. Exp. Bot. 35:525–545.

Reilly, C., 1991. Metal Contamination of Food. 2nd ed. London: Elsevier.

Sterrett, S.B., Chaney, R.L., Gifford, C.H., and Meilke, H.W., 1996. Influence of fertilizer and sewage sludge compost on yield of heavy metal accumulation by lettuce grown in urban soils. Environ. Geochem. Health 18:135–142.

USEPA, 2002. Children-specific exposure factors handbook. EPA/600/P-00/002B. National Center for Environmental Assessment, Washington, DC.

Wong, J.W.C., 1996. Heavy metal contents in vegetables and market garden soils in Hong Kong. Environ. Technol. 17:407–414.

World Health Organisation (WHO), 1989. Report of 33rd meeting, Joint FAO/WHO Joint Expert Committee on Food Additives, Toxicological evaluation of certain food additives and contaminants No. 24, International Programme on Chemical Safety, WHO, Geneva.

An Economical Solution for the Environmental Problem Resulting from the Disposal of Rice Straw

A.A. El Damatty and I. Hussain

Abstract The disposal of rice straw as a by-product resulting from the cultivation of rice is causing worldwide environmental and health problems. Farmers tend to randomly burn rice straw as the most economical method of disposal. This practice does not only generate smoke, but also breathable dust that contains crystalline silica and other health hazard substances. An environmentally friendly process that produces three valuable products is developed in this research. The process is based on a combustion technology using a special reactor manufactured in Canada. Significant amount of energy is released in the form of steam as a result from this process. The rice straw ash (RSA) resulting from this technology is rich in silica and can act as a mineral admixture that enhances the strength and durability of concrete. Liquid rich in potassium results from the hydrolysis of straw and can be used as a fertilizer. A simulation of the entire process, including hydrolysis, drying, chopping and combustion of the straw followed by grinding of the produced ash was conducted on a reduced industrial scale. A study to assess the enhancement in strength and durability of concrete and its resistance to chemical and corrosion attacks was also conducted. The paper also discusses briefly the main findings of a study funded by the Canadian International Development Agency "CIDA" that was carried out to assess the feasibility of such a project in Egypt.

Keywords Rice straw · silica · mineral admixture · fertilizer · energy

1 Introduction

Rice is one of the most important food items of the world. Global production of rice is estimated to be 618 million tonne during the year 2005 (International Rice Research Institute, IRRI). Each tonne of rice produces an equal amount of straw as

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a by-product. In many countries, farmers dispose of rice straw by random burning in the open fields, which tends to be the most economical method of disposal (Mehta 1977). This practice not only generates smoke but also breathable dust that contains crystalline silica and other hazardous substances. This leads to many environmental problems related to human health and safety and diseases related to lungs and eyes are very common in these areas.

Mehta (1979) suggested that combustion of rice husk, another by-product of rice crop, under controlled conditions of temperature, produce ash (rice husk ash – RHA) which is rich in amorphous silica. This ash can be used as an additive for concrete to improve its strength and durability. Nehdi et al. (2003) used a special reactor, manufactured in Canada, to produce RHA. The ash produced by this reactor is of high quality and is rich in amorphous silica and has been proven to be a good additive for concrete. In the current study, the same reactor has been used to produce ash from rice straw (rice straw ash – RSA).

Egypt is one of the countries that face the challenge of rice straw disposal. An extensive research program was conducted as collaboration between the University of Western Ontario (UWO) in Canada and various Egyptian governmental agencies to develop an economical and environmentally friendly solution for this problem. An industrial process leading to three valuable products was developed in this program. The research was conducted in three phases. The first phase involved laboratory testing. The second phase involved a reduced – scale simulation for various components of the process and the third phase involved conducting a viability study for a full-scale industrial process.

2 Description of the Process

A chemical analysis for a sample of rice straw from Egypt was obtained by conducting a complete oxide analysis and the results are presented in Table 1. The analysis revealed that the ash represents about 15% of the total mass of the straw while the rest of the mass is in form of organic materials. The results show that rice straw is rich in silica. If the combustion of the straw is conducted under controlled conditions, this silica can be in the amorphous state, and in this case, it can have a positive effect in enhancing the mechanical properties of concrete.

The core of the developed industrial process is a special reactor called “Torbed” which uses patented technology to a produce a uniform quality of ash. A preliminary combustion test for rice straw was conducted and a phenomenon described as “centering” was observed during this test. During combustion, the tested straw accumulated together and blocked the reactor preventing from completing the test. This phenomenon is attributed to the presence of a high percentage of alkali in the straw composition in the form of Potassium and Sodium. The equivalent alkalis of the straw defined as $Na_2O + 0.658\,K_2O$ is provided in Table 1 showing a value of 10.14% for the tested sample.

Table 1 Inorganic compositions of rice straw (percentage)

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	Equiv. alkali
78.00	0.05	0.51	0.41	0.29	3.38	2.93	10.58	3.18	0.66	10.14

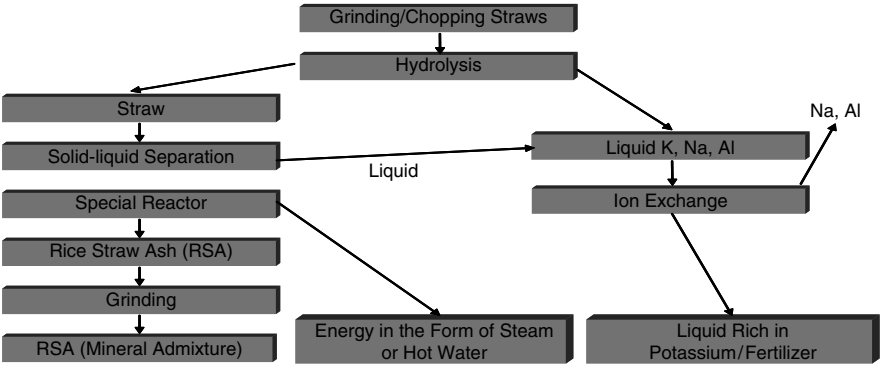

Fig. 1 Flow chart of the entire process

The process starts by chopping the straw to small sizes, typically around 1 in. A hydrolysis process is applied to the straw to reduce the equivalent alkali content to about 2.5%. Saturated straw is then dried to reduce the moisture content to about 35%. The straw is then fed into the Torbed reactor for incineration and the resulting ash is then ground to reach an average particle size of about 7 μm. One tonne of rice straw produces about 150 kg of ash. The calorific value of rice straw is high. The combustion is conducted at an average temperature of 800 °C. During the process, the ash is cooled down to 150 °C and the process of energy exchange leads to the production of hot steam. The combustion of 1 t of straw produces about 5 t of steam. This is equivalent to about 50% of the energy produced by the similar amount of coal.

The liquid resulting from the hydrolysis of straw is rich in potassium, which can be used as an agricultural fertilizer. However, the presence of sodium in the liquid can be harmful to the soil. Either a special ion exchange process can be applied to remove sodium or the hydrolysis can be conducted using a high water to straw ratio such that the amount of sodium can be tolerated. A flow chart of the entire process is provided in Fig. 1.

3 Reduced Scale Simulation of the Entire Process

A reduced scale test that simulates various stages of the proposed process was applied. The following steps were conducted:

(a) Rice straw was first chopped to a fine size.
(b) A large steel tank was constructed to conduct hydrolysis of the chopped straw. A steel screen, with very fine openings size, was constructed and installed inside the tank.
(c) Hydrolysis was conducted to the chopped straw by applying two leaching stages.
(d) It was found that after hydrolysis, the straw had a moisture content of 80%. As such, the straw was dried using a heated oven.
(e) Combustion of the straw was then conducted in the Torbed reactor.
(f) The produced RSA was then ground such that its average particle size was about 7 μm.

Photos illustrating various stages of the process are shown in Figs. 2–5.

Fig. 2 Chopping of rice straw

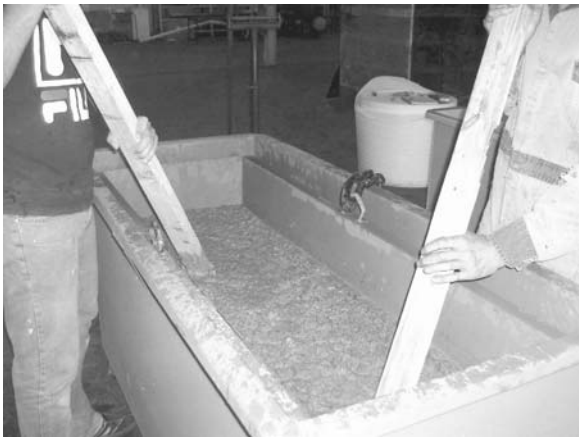

Fig. 3 Hydrolysis of rice straw

Fig. 4 Torbed reactor

Fig. 5 Liquid from hydrolysis

Table 2 Results of oxide analysis of ash resulting from combustion process

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	L.O.I	Total	Equiv. alkalis
RSA	84.65	0.12	0.00	3.99	0.19	1.97	3.49	2.44	0.54	0.26	2.0	99.65	2.14

Oxide analysis was conducted for the ash resulting from this process and the results are given in Table 2. RSA can provide a similar function as Silica Fume (SF) and, therefore, its specifications can be compared to SF, provided in the ASTM C 1240-01 standard. In this standard, a minimum ratio of SiO2 of 85.0% and maximum loss on ignition (LOI) of 6.0% has been specified for SF. The results presented in Table 2 show that the LOI for RSA is less than 6% and the silica content was very close to the value specified in the standards.

4 Behaviour of Concrete Incorporating Rice Straw Ash

A total number of five concrete mixtures including a control mixture were prepared. Four concrete mixtures incorporated RSA and SF as partial replacement of mass of cement. A constant water-to-cementations materials ratio (w/c) of 0.4 was used. ASTM type I cement, natural washed gravel with a maximum particle size of 10 mm and silica sand conforming to ASTM C33 was used in the concrete mixtures. The Superplasticizer dosage was tailored in each mixture to achieve a slump of 90 ± 10 mm. Concrete cylinders were tested for compressive strength at ages of 1, 7 and 28 days whereas to measure the durability of concrete, rapid chloride penetrability test was performed at 7 days, following the procedure mentioned in ASTM C 1202.

5 Compressive Strength Tests

Compressive strength results are shown in Fig. 6. An increase in the 1-day compressive strength was achieved by all RSA concretes as compared to the reference concrete, with concrete having 10% replacement of RSA showing the highest 1-day strength. At 7 and 28 days, the strength of all concretes incorporating RSA and SF outperformed that of the reference concrete. At 28 days, concretes with 7.5%, 10% and 12.5% RSA contents showed increase in compressive strength of 12.7%, 18.18% and 23.2%, respectively, as compared to the reference concrete.

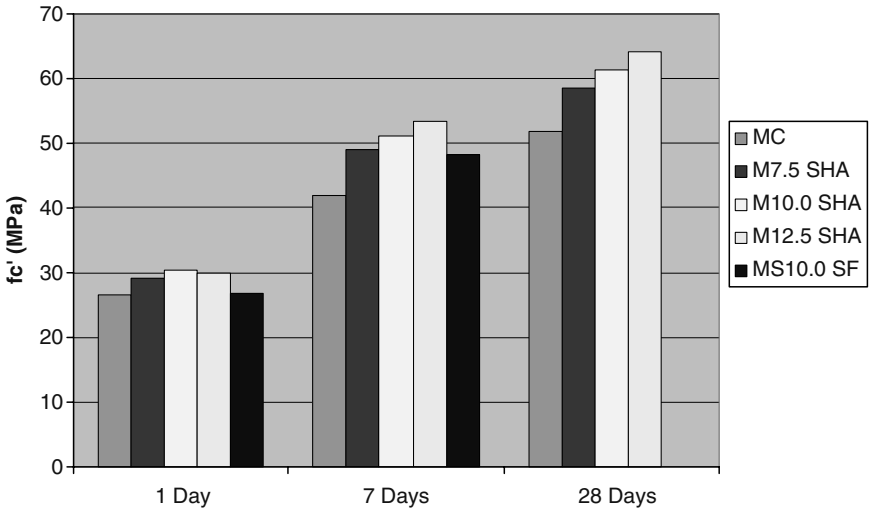

Fig. 6 Compressive strength test results

6 Rapid Chloride Penetrability Test for Durability Assessment

Rapid chloride penetrability tests at 7 days were carried out for all five concretes and the results are presented in Fig. 7 along with the ASTM C1202 classification ranges. All RSA concretes have shown excellent resistance to the chloride ion penetrability and lie either in the very low or low ranges of ASTM classification. Resistance to chloride ion penetrability of RSA concrete is more than that of SF concrete with equal percentage additions.

7 Electrical Conductivity Liquid Resulting from Hydrolysis

Liquid resulting from the hydrolysis of rice straw was tested for electrical conductivity (E.C) in order to measure its salinity and the results are shown is Table 3. This liquid, rich in potassium, can be used as an agricultural fertilizer. E.C is expressed in milli-siemens per centimeter (ms/cm). According to the Department of Agriculture,

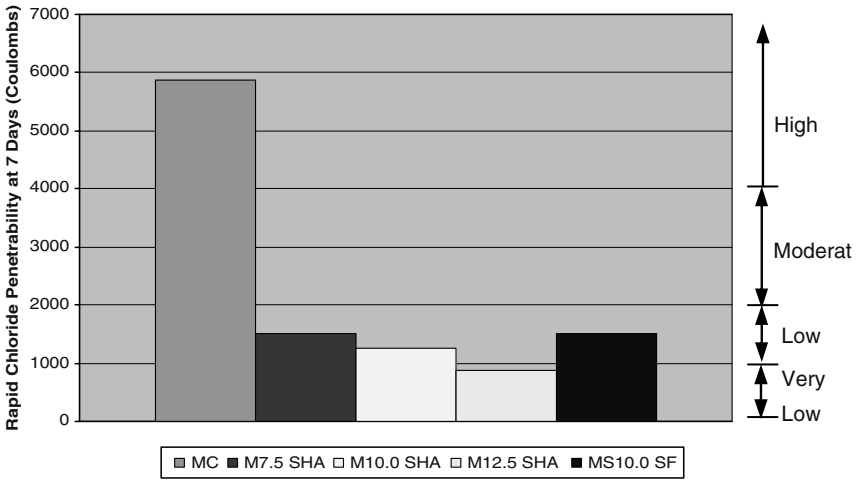

Fig. 7 Rapid chloride penetrability test results

Table 3 Results of electrical conductivity

Stage of hydrolysis	E.C[a] (ms/cm)
I	1.73
II	0.49

[a]E.C value for ordinary tap water is 0.22.

Food and Rural Development of Alberta, Canada (Government of Alberta 2001), the allowed E.C value for a non saline solution should be less than 2 ds/m for a soil depth of 0–60 cm and less than 4 ds/m for a soil depth of 60–120 cm. The results show that the electrical conductivity of the liquid is less than 2 ds/m and therefore, it can be used as agricultural fertilizer.

8 Results of Viability Study

A detailed study was conducted to assess the viability of a full-scale industrial project based on the process described in the study. Although, this project can assist in solving a National problem, its success and sustainability depends to a large extent on the economics of the project. The viability study covered many aspects including the availability and collection of the raw materials, the global demand for RSA as a concrete additive, the potential use of energy, the environmental impact of the project both on the local and global levels and the cost-benefit analysis of the project. Main findings of this study are summarized below:

1. The global annual demand on mineral concrete admixtures will reach a value 1.12 million tonnes by 2013 and the predicted supply of currently available materials can not by far satisfy this demand. As such, a strong market exists for RSA as a concrete additive. The increase in demand on this type of concrete additives is associated with three factors: (a) the natural expansion of the cement and construction industry, (b) the need to optimize the cost effectiveness of concrete by improving its durability and long term performance and (c) the requirement to minimize the environmental impact of cement and concrete production – especially the CO_2 emission.
2. It is more economical to consume the energy resulting from the process either in the form of hot water or steam rather transforming it to electricity, which requires an extra investment to cover the costs of a turbine and a generator. A conducted survey indicated that industries in Egypt are open to the idea of getting their needed supply of steam from a separate rice straw reactor, given that the cost of steam will not exceed its cost based on conventional sources of energy.
3. An environmental impact assessment study revealed that the project has positive impacts on the local level by eliminating many environmental and health problems associated with the current method employed for the disposal of rice straw.
4. On the global environmental level, the process results in emission of carbon dioxide which can be considered as a negative effect in view of the issue of green house emission. However, this hypothesis might be reversed and the suggested process can be considered to have a positive effect on the global environment. The effect of RSA in increasing the strength of concrete leads to a reduction in the structural cross sections and, consequently, a reduction in the consumption of cement. One tonne of RSA can lead to a saving of 3 t of cement. Since the production of cement results in a large emission of carbon dioxide, the net

results associated with the use of RSA in concrete can be a significant reduction in the global emission of carbon dioxide.

5. The value of RSA, energy and liquid fertilizer resulting from processing 1 t of straw is about $84. Given that the cost of 1 t of straw including transportation is about $20; such a project can be economically viable.

9 Conclusions

An industrial process has been developed to produce three valuable products from a waste material, namely from rice straw. A reduced-scale simulation for various components of this process has been conducted. The core of the process is an advanced combustion technology produced in Canada. The three products resulting from this process are: rice straw ash (RSA), significant amount of energy and a liquid fertilizer.

Mechanical properties of concrete specimens reveal the efficiency of the RSA produced using the proposed technology in enhancing the strength and durability of concrete. The processing of 1 t of straw leads to about 5 t of hot steam. This amount of energy is equivalent to 50% of that produced by a similar amount of coal. The third product resulting from the process is a liquid rich in potassium is suitable for use as an agricultural fertilizer. A conducted viability study revealed the strong market demand for RSA as a concrete additive. The combination of RSA, energy and fertilizer makes this project quite viable economically for application in developing countries where rice is cultivated.

References

Government of Alberta, "Salt tolerance of plants", *Agriculture, Food and Rural Development*, 2001.

P. K. Mehta, "Properties of blended cements made from rice husk ash", *Journal of the American Concrete Institute*, V.74, No.9, September 1977, pp. 440–442.

P. K. Mehta, "The chemistry and technology of cements made from rice-husk ash", *Proceedings of UNIDO/ESCAP/RCTT Workshop on Rice-Husk Ash Cement, Peshawar, Pakistan, Regional Centre for Technology Transfer, Bangalore, India*, 1979, pp. 113–122.

M. Nehdi et al., "Performance of rice husk ash produced using a new technology as a mineral admixture in concrete", *Cement and Concrete Research*, V.33, 2003, pp. 1203–1210.

Reversing Africa's Deforestation for Sustainable Development

K. Tutu and C. Akol

Abstract Forests provide goods and services which are not only vital for the survival of the poorest in many African countries, but are also essential for the basic functioning of a wide range of development sectors in the continent. The success of many poverty reduction and economic growth strategies of these countries is thus inextricably linked to the sustainable provision of forest goods and services. This is being severely undermined by chronic and widespread deforestation in the continent. This continues to compromise efforts towards achieving the targets set in millennium development goals, as well as attaining sustainable development in the continent and at the global level. There is therefore an acute need to continue exploring and promoting policy options, measures and models to enhance success in combating deforestation in Africa. This paper explores the significance of deforestation in the continent and helps to advance knowledge and to offer policy and other recommendations to combat this menace in Africa. The paper seeks to contribute to and stimulate cross-sectoral dialogue and actions to combat deforestation. In so doing it will serve to promote and mainstream sustainable forest management principles and measures within the broad agenda of poverty reduction and sustainable development in Africa.

Keywords Africa · sustainable · development · reversing · deforestation · forests · strategies

1 Introduction

The fight against poverty is one of the top most priorities of both the African countries as well as international development policy. So is sustainable development, which is about improving the quality of life for all of earth's citizens without com-

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promising the ability of future generations to meet their needs. Forests and woodland resources are important elements in both poverty reduction and sustainable development strategies of many Africa. In this respect forests provide goods and services that are not only vital for the survival of the poorest of the continent, but which are also essential for the basic functioning of a wide range of development sectors. Forests therefore underpin sustainable development in Africa and at global level. The challenge facing the African continent in particular, is the overwhelming deforestation and degradation of its forests amidst the increasing number of people who are becoming dependent on forest and woodland resources. If immediate solutions to deforestation are not found, efforts to achieve targets set in the millennium development goals as well as attaining sustainable development in Africa will be seriously compromised.

This paper illustrates the significance of forests and explores the extent, causes and consequences of deforestation in Africa. A brief review of strategies undertaken or underway to combat deforestation is made. The paper offers policy and other recommendations to combat the menace of deforestation and foster sustainable development in the continent. It seeks to contribute to and stimulate cross-sectoral dialogue and actions to combat deforestation. In so doing it will serve to promote and mainstream sustainable forest management principles and measures within the broad agenda of poverty reduction and sustainable development in Africa.

2 Extent and Importance of Forests in Africa

There are several definitions of forests according to different organizations. The FAO definition, which is generous, classifies forests as land with a tree canopy cover of more than 10% and an area of more than half a hectare. FAO's definition of forests include natural and plantation forests but excludes stands of trees established primarily for agricultural plantations such as fruit tree and oil palm plantations and trees planted in agroforestry systems.

Forests are estimated to cover an area of 635 million representing 16% of the global forest area and 21% of Africa's land area. One percent of the forest area is classified as forest plantations and protected forests cover an estimated area of 75,885,000 ha (12% of total forest area) (Kidd 2005). The vast majority of Africa's forests are found in West and Central Africa (FAO 2006). However more than 70% of Africa's remaining rainforests are located in the Central African subregion, covering about 720,000 square miles (1.875 million square kilometres). The bulk of forests in this subregion are found in the Congo Basin in the countries of the Democratic Republic of Congo, Congo and Gabon (Butler 2006b). The Congo Basin also contains the second largest continuous tropical rainforest in the world. In Africa, most forest plantations are found in Northern Africa, which is dependent on plantations in the absence of natural forests (FAO 2006).

Forests provide multiple goods and services that are vital for poverty reduction and sustainable development in Africa and at global level. Over two-thirds of

Africa's 600 million people rely directly or indirectly on forests for their livelihoods including food security (CIFOR 2005). It is estimated that forests account for an average of 6% of Gross Domestic Product (GDP) in Africa, which is the highest in the world (NEPAD 2003). About 80% of the energy used in Africa is wood biomass based. Fuelwood is predominantly used in the rural areas, while in urban areas, charcoal is used.

Forests are also important in the recharge of water bodies as well as controlling water flow. In this respect they are vital in the health of communities, agricultural production and electricity power generation, which depend on this water.

Forests and woodlands are critical in biodiversity conservation. Africa is home to 25% of the world's remaining tropical rainforests and contains 20% of the world's biodiversity hotspots (CIFOR 2005). The Congo Basin forest alone harbors the most diverse assemblage of plants and animals in Africa including over 400 mammal species, more than 1,000 bird species, and over 10,000 plant species of which about 3,000 are endemic. Only in Central Africa do forest elephant, gorilla, forest buffalo, bongo, and okapi occur in large numbers across large areas of forest (CBFP 2005).

Forests are vital indeed in combating land degradation and desertification and mitigating climate change, which pose serious threats to agricultural production among other economic sectors.

3 The Threat of Deforestation

According to FAO, deforestation is the conversion of forests to another land use (such as agriculture, pasture, water reservoirs and urban areas) or the long-term reduction of the tree canopy cover below the minimum 10% threshold.

There are many root causes of deforestation. No one factor takes place independently, and most studies point to a combination of factors as the key driving forces behind deforestation (Clausen et al. 2003). The most cited ones in Africa are the high levels of poverty, hunger, high population growth rates, conflicts, market forces, poor resource and economic development policies, and insufficient long-term funding. The more visible direct causes of deforestation are conversion of forests into agricultural land, large-scale shifting cultivation (slash and burn), logging, fuelwood collection including clear-cutting for charcoal production (Allen and Barnes 1985). The others include forest conversion for permanent pasture, open pit mining and large-scale mining operations, large roads and infrastructure projects, wildfires that destroy forest canopy, dam construction, volcanic eruptions, chemical defoliants and urban expansion (Roper 1999). Both the underlying and direct causes of deforestation operate in an interlinked manner.

Although the direct and indirect environmental impacts of commercial logging may be significant, it is generally not thought to be the predominant cause of tropical deforestation (Burgess 1993). However, it should be noted that in many African countries, logging does not take place in the prescribed way, neither is there replanting by loggers with the result that most logging results in deforestation. In a

paper done for the world Bank on the consequences of log ban in Ghana, it was found that lack of in-depth processing of timber logs led to more timber being cut and increase in deforestation (Tutu et al. 1992).

In Africa, deforestation constitutes a crisis that is extensive. Between 2000 and 2005, Africa posted the second highest rate (4 million hectares per year) of loss of its forests (FAO 2006). In terms of loss of its rainforest, Africa lost the highest percentage of rainforests during the 1980s, 1990s, and early 2000s of any biogeographical realm (Butler 2006b). Africa's forests are the most depleted of all tropical regions with only about 30% historical stands still remaining. http://www.unep.org/geo/geo1/ch/ch2_3.htm. FAO data shows that tropical deforestation rates increased by 8.5% from the 1990s to 2000–2005 while loss of primary forests may have increased by 25% over the same period (Butler 2006a).

West African rainforests are highly fragmented. The only large forest blocks remaining are in the border zone between Liberia and Ivory Coast. In Ghana, small remnants rainforest patches are restricted to protected areas (Butler 2006b).

There are varying degrees of rates of deforestation among countries. For example the deforestation rates range from 0.4% in the Democratic republic Congo (DRC), 0.5% in Liberia, 0.6% in Sierra Leone, 1% in Ivory Coast, to 1.3% in Ghana http://www.worldwildlife.org/bsp/publication/africa/127/congo_06.html.

In many African countries, between 60–85% of the total land area, which was originally covered with humid tropical forests, has been deforested. In Ghana, for instance, the total forest cover that stood at 8.2 million hectares at the turn of last century (1900s) decreased to 1.6 million hectares by 2000. According to Butler (2005), in the period between 2000 and 2005, Nigeria lost 55.7% of its primary forests, topping the world in deforestation of this type of forests).

With these alarming rates of deforestation, many countries in Africa therefore face a danger of incurring high social, economic and environmental costs from deforestation. For instance, it is estimated that about 20% of annual green house gases (GHG) emissions result from deforestation and forest degradation (Clausen et al. 2003). In a recent global warming conference held at UNEP in Nairobi, losses from extreme weather were estimated to reach $1 trillion in a single year by 2040 (Wallis, 2006). This is attributable to climate change and global warming (Reuters 2006). In Zambia for example, ECA (2002) quotes an estimated cost US$15 million as requirement over a 5-year project cycle for mitigating climate change brought about by deforestation in the country. Wong et al. 2005 report that deforestation has increased the frequency of floods and droughts, and unsustainable clearing of land for agriculture has contributed to drops in soil fertility in Mozambique.

4 Strategies and Measures Taken Combat Deforestation

Over the years many initiatives and strategies with a bearing on sustainable forest development in general and combating deforestation in particular have been undertaken in Africa and at the global level. These have had varying degrees of success in combating deforestation and fostering sustainable forest management

as a whole. Never the less they have provided useful lessons learnt that serve to inform the future direction in combating deforestation. Some of the main initiatives include the following:

(a) The FAO, World Bank and other donors initiated the Tropical Forestry Action Plan (TFAP), to combat deforestation through the development and implementation of forest action plans in individual tropical countries. Many African countries were supported through this large initiative that begun in 1985. According to Winterbottom (1990), 'the needs to control deforestation and to reclaim lost forestlands' were greater than ever before, 5 years into the implementation of TFAP. Rice et al. (2001) states that, 'despite the high volume of spending, the TFAP eventually came to be seen as a failure because it was not curbing deforestation; increasingly, the plan was viewed in many countries simply as a way of promoting more forest development.' Other flaws identified by the assessment of the TFAP by the World Resources Institute (WRI) in 1990 were that: the needs and rights of forest dwelling people were not stressed in the original plan and it was wrongly assumed that increased funding with the forest sector would solve problems whose roots reach deep into economic and social policies made and observed out side the forest sector (Winterbottom 1990). The WRI assessment concluded then, that increased attention to policy reform both within and outside the sector, and improved land-use planning and coordination with agricultural and other development programs could help turn the tide against uncontrolled deforestation and wasteful depletion of tropical forest resources (Winterbottom 1990). To a great extent these concerns and challenges remain relevant today in terms of enhancing the success of other forestry programs in addressing deforestation.
(b) Community forestry has been a driving force in the management of both natural and man-made forests since the 1970s (Clausen et al. 2003). Tree planting on farmlands, agroforestry, community-based natural forest management (CBNFM) within existing natural forests and collaborative forest management (CFM) have been promoted. These strategies are aimed at not only restoring and increasing forest cover but also to enhance community benefits from the management of trees and forests.

Through these strategies, communities have been given access to forest reserves land to plant trees. Controlled access to natural forest resources has also been granted. Sharing of revenue and other forest co-management schemes have also evolved. In order to enhance success and community benefit from forest management and development programs, some of the key lessons that have emerged from these initiatives are that: clear community land tenure and user rights for resources are extremely important; attention should be paid to increasing access to markets; community organizational and enterprise capacity development is necessary; and ethnic and community diversity issues especially in relation to forest groups need to be addressed (Clausen et al. 2003; Arnold 2001; Sayer et al. 1997).

(c) National forest programmes (NFP) have been promoted internationally as fundamental tools that provide a policy and planning framework for translating the principles of sustainable forest management into domestic action. About two

thirds of African countries have NFPs at different levels of implementation (FAO 2006). The NFPs have resulted in the adoption of more robust forest policies and legislation and establishment of more accountable forest administrations. The policies and legislations embrace sustainable development principles including multi-stakeholder participation in the management and development of forest. The case in point is the new Uganda forestry law resulting from the NFP. This law requires the designation of national tree planting days. There is however a slow pace in implementing the priority interventions identified in the NFP processes. This is partly due to limited funding resulting from the low priority accorded to the sector and the scanty integration of NFP priorities into the poverty reduction strategies at national level.

(d) Market based instruments such as payment for forest ecosystem services and forest certification have recently emerged as important tools in promoting sustainable forest management. In this respect, the importance of forests as a vehicle to offset climate change has become widely recognized. However a lot remains to be done to foster a broader understanding of the role and to operationalize schemes on payment for forest services and forest certification in relation to combating deforestation in Africa. With respect to adopting forest certification in developing tropical countries, inadequate land ownership and/or tenure rights, poor governance, high cost of forest certification and limited access to markets for certified forest products are listed among the main constraints (Becker).

While it has not been possible to quantify the contribution of each of these various strategies to tackling deforestation, FAO (2006) indicates that during the period 2000–2005, there was a slight decline in the net loss of forests in Africa owing to forest planting, landscape restoration and natural expansion of forests in the region.

5 Moving Forward in Reversing Deforestation

Reversing deforestation entails the halting of further net loss of forest cover and ensuring forest restoration and the development of forest plantations. In these endeavours, causes of deforestation must be addressed taking into account lessons learnt to date. In order to foster sustainable development social, economic and environment aspects need to be kept in sharp focus in forestry programs. The required strategies to reverse deforestation should therefore encompass the development of a clear understanding and appreciation, and the quantification of the multiple benefits of forests and trees to the poor and to a range of development sectors. Information quantifying the benefits of forest goods and services in Africa is scanty and limited to selected goods and services, and more over in a few countries. The required strategies should also secure and guarantee equitable and increased flow of benefits from forest management and development to key stakeholders. Further more these strategies should seek to engage the local community, the private

sector and government sectoral agencies to participate and invest in forest management and development.

Against this background, the following mutually interactive strategies and actions are recommended to improve the success of efforts to reverse deforestation in Africa.

1. A conscious and scaled-up effort to transform agriculture and rural livelihood will be one of the most important strategies to address poverty and deforestation in Africa. Agriculture should be transformed by using relevant technologies at the production level and ensure value addition in all the chains of the industry. Farmers should be resourced to undertake intensive cultivation by using appropriate and high productivity technologies. This will ensure the reduction in extensive cultivation, increased agricultural productivity and output, increased incomes, poverty eradication and above all reduced deforestation.
2. Sustainable livelihood in the rural and urban areas must mean a change in the energy use. The use of fuelwood and charcoal must be reduced to the lowest minimum through energy substitution. In many African countries, there are several rural areas that have been electrified. Unfortunately, to a large extent, it is being used for lighting not as energy for household consumption and production purposes. Some rough calculations have shown that it costs slightly less per household to use gas rather than charcoal that the urban households prefer to use. They are unable to make the substitution because of initial high fixed cost of buying gas stoves. Through community partnerships, poor people must be assisted to form associations for rural credit mobilization (such as the Susu system in Ghana) to enable them purchase gas and electric stoves. Innovative hire-purchase (credit) system should be introduced to enable urban and rural households purchase these stoves.

In cases where the cost of electricity or gas is the constraint, subsidies that are equal to the cost of deforestation should be put on them to enable as many people do the energy switch. In many cases however, it is impossible to use gas or electricity for household energy purposes. In this case, improved cooking stoves, fast growing trees for fuelwood must be encouraged.

3. The gap between preaching and practice should indeed be reduced. More assistance provided to the forest sector to combat deforestation should be targeted at integrated interventions at local governments, the private sector and the local community levels. This is urgently required to translate the new policies into action and to test the efficacy of these policies in combating deforestation. And more over this has the potential to directly tackle deforestation on site and meet livelihood needs of the forest dependent communities.
4. Local communities and the private sector should be attracted to participate in sound forest management and development activities through policies that encourage greater community and private sector tenure and access to forest land and resources for use and tree planting activities. In implementing these policies the practice of restricting participatory forestry to degraded or poorer areas of

the forests should be avoided. Leasing of forests and offering of concessions and contracts to the local community should be promoted. In this regard the development of local community organizational and forest enterprise management capacity is essential. The success of these policies can be enhanced if they are implemented in tandem with those that fight corruption and promote openness and accountability in the forest sector.

5. More holistic solutions involving other sectors in combating deforestation are needed. Linkages between forestry and other sectors and in particular with poverty reduction need to be further determined and elaborated through targeted research. The political leadership in particular and other key stakeholders need to be to be familiarized with these linkages using high impact communication strategies and tools. This is key to the development of political leadership, which will enhance high level and cross-sectoral dialogue and appreciation of measures to combat deforestation. It will also facilitate the integration forest programs in other sectoral programs and therefore the mobilization of multi-sectoral and multi-tier support and action to combat deforestation.
6. In particular the understanding of and schemes for payment for forest ecosystem services need to be developed. Economic valuation of forest ecosystem services should therefore be promoted and undertaken. In combating deforestation through forest ecosystem services based schemes such as carbon sequestration that have global level benefits, local community needs that ought to be met from other services and goods provided by the forest, should remain in focus and planned for.
7. Unlike many social and economic development interventions, initiatives to combat deforestation like other environment related programs need long-term investments. Forestry programs in general and especially those targeted at combating deforestation should therefore be designed with long-term and adequate resource commitments.
8. The emergence of Regional and subregional initiatives such as the Environmental Initiative of the New Partnership for Africa's Development (NEPAD), the Central African Forest Commission (COMIFAC), and the Congo Basin Forest Partnership (CBFP) present opportunities to galvanize action to combat deforestation. They have a great potential in addressing cross-boundary issues related to deforestation. These initiatives however need to be linked and coordinated with national development process to accelerate their implementation and achieve greater impact on deforestation.

6 Conclusion

Deforestation threatens the very basis of economic growth and poverty reduction in the Africa and undermines prospects of sustainable development. The chronic and widespread deforestation in Africa is a result of diverse and intertwined economic, social, environmental and political pressures. The task of reversing

deforestation is complex one. Despite the numerous forestry initiatives that have been undertaken to among others things combat deforestation, little progress has been made to date.

In order to make a significant dent on deforestation, sustained long term multi-sectoral and multi-layered strategies and approaches are need. Policy frameworks that encourage community participation through securing local community benefits from forest management and development should be promoted to underpin these measures. In this regard, empowerment of the community and the private sector, through organisational capacity building should not be relegated in forestry programs. Many interventions should be targeted at field level. It is crucial to integrate and address the needs of the local community in forestry programs of global dimension such as mitigating climate change.

Investment in measures to tackle deforestation and ensure sustainable forest management can and should be enhanced by improving access to micro credits, and increase access to markets and opportunities for value addition to forest products. Opportunities for increased resources for tackling deforestation are presented by the emerging schemes for payments for forest ecosystem services, forest certification and regional and sub regional initiatives.

References

Allen, J.C. and Barnes, D.F. (1985) The causes of deforestation in developing countries. Annals of the Association of American Geographers 75:163–184.

Arnold, J.E.M. (2001) Forestry, poverty and aid. CIFOR Occasional Paper No. 33.

Barnes, R.F.W. (1990) Deforestation trends in Tropical Africa. African Journal of Ecology 28:161–173.

Becker, M. (2004) Barriers to forest certification in developing tropical countries. Paper for Master's in Forest Conservation (M.F.C.), University of Toronto, Faculty of Forestry. Accessed from http://www.forestry.utoronto.ca/pdfs/becker.pdf

Burgess, J.C. (1993) Timber production, timber trade and tropical deforestation. Ambio, Stockholm [AMBIO] 22(2–3):136–143.

Butler, R.A. (2005) Nigeria has worst deforestation rate, FAO revises figures. Accessed on December 20, 2006 from *Mongabay.com*. Website: http://news.mongabay.com/2005/1117-forests.html

Butler, R.A. (2006a) A world imperiled: Forces behind forest loss. Accessed on June 22, 2006 from *Mongabay.com*. Website: http://rainforests.mongabay.com/0801.htm#tables

Butler, R.A. (2006b) Afrotropical realm: Environment profile. Accessed on December 20, 2006 from *Mongabay.com*. Website: http://rainforests.mongabay.com/20afrotropical.htm

CBFP (the Congo Basin Forest Partnership) (2005) The forests of the Congo Basin: A preliminary assessment. Website: http://www.cbfp.org/docs_gb/forest_state.pdf

CIFOR (2005) Contributing to African development through forests. Strategy for engagement in sub-Saharan Africa. Website: http://www.cifor.cgiar.org/publications/pdf_files/Books/PCIFOR0501.pdf

Clausen, R., Gibson, D. et al. (2003) USAID's Enduring Legacy in Natural Forests: Livelihoods, Landscapes and Governance Volume Two: Study Report. USAID.

ECA (United Nations Economic Commission for Africa) (2002) Economic impact of environmental degradation in Southern Africa. ECA/SRDC/SA/PUB/03.

FAO (2006) Global Forests Resources Assessment: Progress Towards Sustainable Forest Management. Rome.

Kidd, M. (2005) Forest issues in Africa. Website: http://www.joensuu.fi/unep/envlaw/materi2005/kidd.doc

NEPAD (2003) Action plan for the environment initiative. New Partnership for Africa's Development, Midrand. Website: http://nepad.org/2005/files/reports/action_plan/action_plan_english2.pdf

Reuters (2006) Disasters losses may top one trillion dollars per year by 2040. In Environmental News network (ENN). Website: http://www.enn.com/today.html?id=11659

Rice, R.E., Sugal, C.A., Ratay, S.M., and Fonseca, G.A. (2001) Sustainable forest management: A review of conventional wisdom. Advances in Applied Biodiversity Science, Washington, DC: CABS/Conservation International, Vol. 3, pp.1–29.

Roper, J. (1999). Deforestation: Tropical Forests in Decline, Canadian International Development Agency, Hull, Quebec, Canada.

Sayer, J.A., Vanclay, J.K., and Byron, N. (1997) Technologies for sustainable forest management: Challenges for the 21st century. CIFOR Occasional Paper No. 12.

Wallis, D. (2006) Reporting for Reuters on UNEP Conference on Climate Change in Nairobi, November 15, 2006.

Winterbottom, R. (1990) Taking Stock: The Tropical Forestry Action Plan After Five Years. WRI.

Wong, C., Roy, M, Duraiappah, A.K. (2005) Linkages between poverty and ecosystem services in Mozambique. *Connecting Poverty and Ecosystem Services: Focus on Mozambique. IISD*. Website: http://72.14.203.104/search?q=cache:wtnFmBdVVMsJ:www.eldis.org/static/DOC20108.htm±IISD±deforestation±poverty&hl=en&gl=us&ct=clnk&cd=10

Tutu, K. Asante, E., and Barfour, O. (1992) Consequences of Log Ban in Ghana. Technical paper for the World Bank, Accra.

Websites:

http://www.mongabay.com/rates_africa.htm. African Deforestation & Forest Data

http://www.unep.org/geo/geo1/ch/ch2_3.htm. Major Environmental Concerns

http://www.worldwildlife.org/bsp/publication/africa/127/congo_06.html. Deforestation in Central Africa: Significance and Scale of the Deforestation.

Life Cycle Assessment of Chocolate Produced in Ghana

A. Ntiamoah and G. Afrane

Abstract Life Cycle Assessment (LCA) has lately emerged as a comprehensive tool for environmental management, and is also becoming increasingly important in the development of cleaner production schemes. Conducting an LCA involves collecting data on raw material and energy consumption and on waste emissions to air, water and land. Data is collected for every stage of the life cycle of the product, from mining or cultivation of the raw materials through to processing, transporting, consumption and disposal. Based on a relevant functional unit for the system under study, the collected data is aggregated and modeled into a life cycle inventory, which in turn is classified and characterized to determine the environmental impacts of the entire system. The International Organization for Standardization (ISO) has standardized the process for conducting LCA in their ISO 14040 series. Many companies have turned to a life-cycle approach in an attempt to properly assess the full environmental impact of their products.

This paper presents an environmental life cycle analysis of chocolate produced in Ghana. The study was conducted in accordance with the international ISO procedural framework for performing and presenting LCA results. The product's life cycle stages, involving the cocoa supply chain, i.e. cocoa beans production, beans transportation and storage and the industrial processing of beans and chocolate manufacturing stages, were studied. The total environmental impacts associated with chocolate production and the relative contribution of each life cycle stage to the impacts are presented and discussed. The functional unit on which the analysis was based is the production of 1 kg chocolate.

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Keywords LCA · chocolate production · cocoa supply chain · environmental impacts

1 Introduction

Cocoa, *Theobroma cacao*, ranks third in global agricultural export commodities following coffee and sugar. About 70% of the world's cocoa is grown in West Africa, with Ghana being the second largest producer, coming after her western neighbour Côte d'Ivoire. Chocolate manufacturing consumes about 90% of the world's cocoa production. Worldwide demand for chocolate is increasing due to its perceived nutritional and health benefits (*www.cabi-commodities.org*; ICCO 2004). Currently Ghana processes about 35% of its cocoa beans into butter, liquor, cake, powder and chocolate for both the local and international markets. Chocolate made from Ghana's premium quality cocoa beans, is acclaimed to be one of the finest in the world (Awua 2002; Appiah 2004).

With the growing awareness and concerns about natural resource depletion and environmental degradation, the impact of production processes on the environment and lifestyles has become a key modern issue. The impact of food production has attracted increasing interest because of the scale and relevance of food production. Not only the content and quality of foods are important to consumers these days, but also the environmental impacts of farming, processing and transporting to the market are also becoming important issues (Ellingsen and Aanondsen 2006). There is thus a growing need for the development of methods to better understand and address the environmental impacts associated with products and processes. One of the techniques gaining popular acceptance as an environmental management tool is life cycle assessment (LCA). LCA addresses the environmental aspects and potential environmental impacts throughout a product's life cycle from raw material acquisition to production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave) (ISO 14040). As an internationally accepted tool, guided by international standards in ISO 14040 (1997), ISO 14041 (1998), ISO 14042 (2000) and ISO 14043 (2000). LCA is being used by many organizations to help in effective environmental decision-making. This study aimed to introduce LCA to the cocoa industry in Ghana and specifically conduct LCA on chocolate, which is the main product derived from cocoa.

1.1 Relevance of the Study

The study will provide LCA data to the Ghana Cocoa Board (COCOBOD) and other stakeholders of the Ghanaian cocoa industry. This information can be used to prioritize measures that can be taken to improve the environmental performance of the industry. It will also improve on the competitiveness of locally produced cocoa products on the increasingly environmentally sensitive global market.

2 Goal and Scope of the Study

The goal of the study was to identify and quantify the potential environmental impacts associated with chocolate production, focusing attention on the cocoa supply chain. The following objectives were identified:

(i) To contribute to LCA awareness creation and application in developing countries
(ii) To identify and quantify key environmental impacts along the chocolate production chain, and to assess the relative contribution of each stage of production to the identified environmental impact categories
(iii) To suggest a number of improvement options or impact reduction measures based on the results obtained

The main ingredients in chocolate are cocoa butter and cocoa liquor, which are obtained from the cocoa beans. In addition, sugar, milk, vanillin and emulsifiers may be added. However, only the environmental impacts resulting from the acquisition of cocoa butter and cocoa liquor (which constitutes about 47.85% of the chocolate studied) was included in this work. Hence the system was sub-divided into four main life cycle stages as follows: cocoa production on the farms, transportation of cocoa beans to processing factory, industrial processing of cocoa into cocoa liquor and butter, and mixing of cocoa liquor, cocoa butter and other ingredients to produce the chocolate. The following aspects were excluded from the study due to lack of relevant data: distribution and consumption phase of the product, including disposal of packaging and expired food. The functional unit chosen is the production of 1 kg chocolate bar. All the inputs and outputs in the Life Cycle Inventory (LCI) and impact scores produced in the Impact Assessment phase were expressed with reference to the functional unit.

3 Life Cycle Inventory (LCI) Analysis

This phase involves identifying and quantifying the inputs and outputs associated with each of the life cycle stages considered. The inventory analysis consists of two major steps; data collection and data processing.

3.1 Data Collection

Data for cocoa production were collected by paying site visits to farms and through interviews with cocoa farmers and researchers at the Cocoa Research Institute of Ghana (CRIG). Background data on production of fertilizers and pesticides, transportation and electricity generation were included using the eco-invent database and the GaBi 4 LCA database. Emissions due to fertilizer and pesticide usage were quantified

using estimation methods (Hauschild 2000; Heathwaite 2000). A state owned cocoa processing company, which is considered state of the art, was selected for detailed study and data gathering on cocoa processing and chocolate manufacturing.

3.2 Data Processing

The data collected were adjusted to values that relate to the functional unit. The data were then modeled into environmental inputs and outputs; and aggregated to result in an inventory table, which is a collection of all normalized (scaled) values for all inputs and outputs for all the different life cycle stages considered in the study.

4 Life Cycle Impact Assessment

Classification and Characterization, which are the mandatory steps in the life cycle impact assessment phase, according to ISO 14042 (2000), were applied to the inventory data to assess their impacts on human health and the environment. The following impact categories of concern were assessed: global warming, acidification, eutrophication, photochemical ozone creation, freshwater aquatic ecotoxicity, terrestrial ecotoxicity, human toxicity and ozone layer depletion. The life cycle impact assessment method developed by the Centre for Environmental Science, University of Leiden, called the CML 2001 method and the GaBi 4 LCA software were used for this phase.

5 Results and Discussion

The characterization results (the overall impact scores) for the production of 1 kg chocolate in Ghana based on the CML 2001 method, is presented in Table 1 and illustrated graphically in Fig. 1. As shown in Fig. 1, the most significant impacts associated with the chocolate production chain in Ghana are freshwater aquatic ecotoxicity, human toxicity and global warming potentials. The relative contributions of the various life cycle stages to the overall impact scores are also presented in Fig. 2.

The cocoa production stage was found to make almost 100% contributions to the impact categories of freshwater aquatic eco-toxicity and human toxicity. In 2001, the government of Ghana initiated moves to increase cocoa production. These moves include mass spraying of cocoa farms with pesticides and distribution of specially formulated fertilizers across the country. These toxicity impacts were found to be mainly caused by the pesticides and the heavy metals present in the

Table 1 The overall environmental impact score for the production of 1 kg chocolate in Ghana, in absolute values, based on the CML 2001 method

Environmental impact category	Overall impact score	Unit
Acidification potential (AP)	9.7351E-03	kg SO_2-equiv
Eutrophication potential (EP)	9.1568E-04	kg PO_4^{3}-equiv
Freshwater aquatic ecotoxicity potential (FAETP)	5.0797E + 00	kg [a]DCB-equiv
Global warming potential (GWP)	3.5602E-01	kg CO_2-equiv
Human toxicity potential (HTP)	4.4426E + 00	kg [a]DCB-equiv
Ozone layer depletion potential (ODP)	4.9805E-09	kg [b]R11-equiv
Photochem. ozone creation potential (POCP)	9.3002E-04	kg Ethene-equiv
Terrestric ecotoxicity potential (TETP)	6.3796E-03	kg [a]DCB-equiv

[a]DCB is 1, 4 dichlorobenzene, [b]R11 is trichlorofluoromethane.

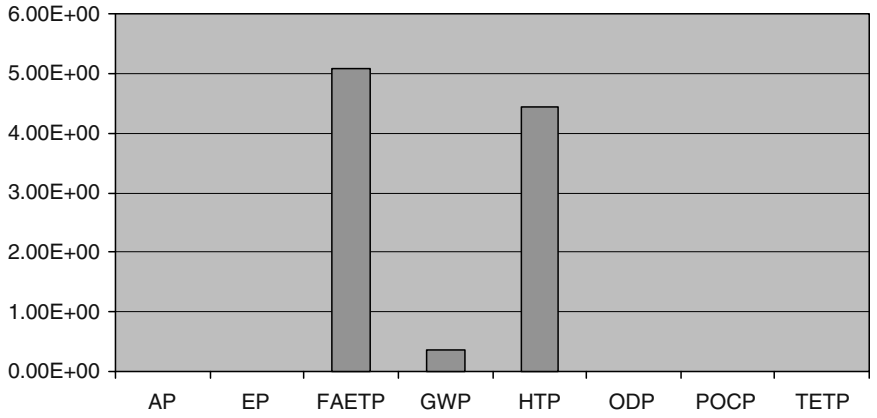

Fig. 1 Characterization results for the production of 1 kg chocolate in Ghana

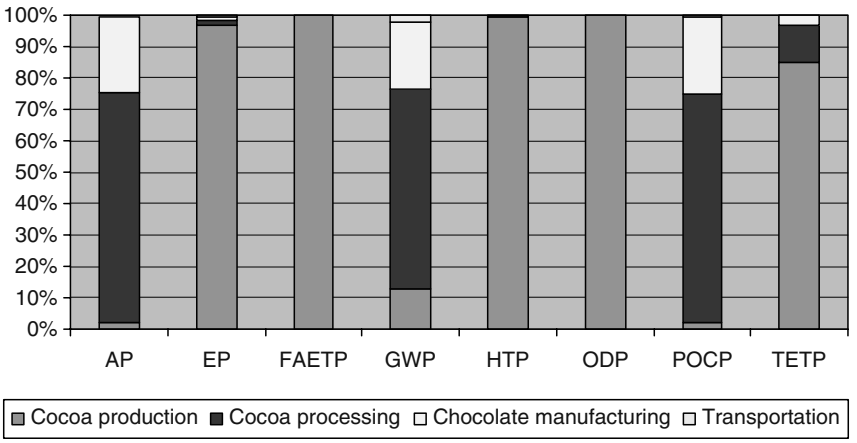

Fig. 2 Relative contributions by life cycle stages to overall impact scores

fertilizers used in cocoa production. Industrial processing of cocoa beans however made the largest contribution to global warming potential (63.70%). This impact was found to be mainly caused by the use of diesel for steam generation and roasting of cocoa beans. Chocolate manufacturing and transportation are relatively the most environmentally friendly of the life cycle stages, since their contributions to the impact categories considered were not very significant. The transportation stage is the least important in terms of environmental impacts, whilst chocolate manufacturing is intermediate between cocoa processing and transportation.

6 Conclusions and Recommendations

This has been an initial investigation to identify and quantify the key environmental impacts associated with chocolate production in Ghana. Even though the actual chocolate manufacturing stage can be said to generate less environmental impacts, some significant impacts namely, freshwater aquatic eco-toxicity, human toxicity and global warming occur during the cultivation and processing of the main raw materials. The study therefore recommends that environmental improvement actions should be focused on the cocoa production and processing stages of the product's life cycle, particularly on agrochemicals and fossil fuels inputs. In this respect, the effort being made by government through the Cocoa Research Institute of Ghana (CRIG) in the development of cost-effective biological control and an integrated pest management system, adequate soil fertility management, continued farmers education and extension services, and introduction of early-bearing, high-yielding and disease-tolerant cocoa varieties, in a programme dubbed Cocoa High Technology Project (COCOA HI TECH) which is now on a pilot basis in the Eastern Region of the country (Appiah 2004), is highly welcome. Early implementation of these strategies across the country would further enhance the environmental friendliness of cocoa production in Ghana.

Future studies could expand the system boundary to include the product distribution and consumption phase of the life cycle and also include the environmental impacts coming from the production of packaging, and other ingredients in chocolate such as sugar and milk. This will provide a comprehensive picture of the overall environmental burdens associated with the life cycle of the product.

In carrying out this study some European LCA databases namely, the Swiss Ecoinvent LCA database and the GaBi 4 LCA database, were consulted for certain background data that were not locally available. These included data on production of pesticides, fertilizers, diesel and electricity, as well as emissions resulting from transportation. According to Mungkung et al. (2006), this can limit the representativeness and hence the reliability of LCA results.

The results of LCA are being used for product improvement, product comparison, eco-labelling and public policy formulation among others. Clearly developing countries cannot be left behind in the adoption of LCA as an analytical tool if we want to produce environmentally and socially acceptable goods for the current

international market. The major challenge now is to develop ready-to-use LCA databases (providing inventory data on the various energy generation systems, and some widely used intermediate products, etc.) that are relevant to the conditions prevailing in these countries, as has been done in several developed countries. These data can then be adapted by local LCA practitioners to help reduce the time and cost involved in collecting data along a product's entire life cycle. The UNEP/SETACT life cycle initiative is helping in this direction. The aim of the initiative is to facilitate a global application of the tool, both in rich and poor countries, and in big companies and SMEs.

Acknowledgments The UNEP/SETAC Life Cycle Initiative awarded the GaBi 4 LCA software used for this project. The authors would like to thank the following people for their contributions: Frank Asante (Cocoa Processing Company, Tema), Gyima Gyamfi (Cocoa Swollen Shoot Virus Disease Control Division of COCOBOD, Kumasi), Kofi Acheampong and James Buabeng (CRIG) and Dr. Lawrence Darkwah, chemical engineering department, Kwame Nkrumah University of Science & Technology, Ghana.

References

Appiah, M.R. (2004): Impact of cocoa research innovations on poverty alleviation in Ghana. Ghana Academy of Arts and Sciences Publication, Accra.

Awua, P.K. (2002): The success story of cocoa processing and chocolate manufacturing in Ghana – The success story that demolished a myth. David Jamieson, Saffron Walden, Essex.

Ellingsen, H. and Aanondsen, S.A. (2006): Environmental impacts of wild caught cod and farmed Salmon – A comparison with chicken. Int J LCA 11(2): 122–128.

Hauschild, M. (2000): Estimating pesticide emissions for LCA of agricultural products. In: Weidema, B.P. and Meeusen, M.J.G. (eds) Agricultural Data for Life Cycle Assessment, Vol. II. The Hague: Agricultural Economics Research Institute (LEI).

Heathwaite, L. (2000): Flows of phosphorous in the environment: Identifying pathways of loss from agricultural land. In: Weidema, B.P. and Meeusen, M.J.G. (eds) Agricultural Data for Life Cycle Assessment, Vol. II. The Hague: Agricultural Economics Research Institute (LEI).

ICCO (2004): International Cocoa Organisation. 2003/2004 annual report. Available from http://www.icco.org.

ISO 14040 – Environmental management – Life cycle assessment – Principles and framework (1997).

ISO 14041 – Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis (1998).

ISO 14042 – Environmental management – Life cycle assessment – Life cycle impact assessment (2000).

ISO 14043 – Environmental management – Life cycle assessment – Life cycle interpretation (2000).

Mungkung, R., Udo de Haes, H. A., and Clift, R. (2006): Potentials and limitations of life cycle assessment in setting ecolabelling criteria: A case study of Thai shrimp aquaculture product. Int J LCA 11(1): 55–59.

Sustainable Production of Traditional Medicines in Africa

O.A. Osunderu

Abstract Since the dawn of history, mankind has been actively experimenting with a variety of available plants as means for food, alleviation of pain and to safeguard its health and promote improved quality of life. Over the years, traditional knowledge, science and technologies have accumulated to form a rich background of cultural heritage.

In Africa, over 70% of the population depends on traditional medicine (Federal Ministry of Science and Technology, 1985) because the rich resources of traditional remedies and practitioners are available and accessible.

However most Government/policy makers and financial investors do not pay much attention to herbal medicine as a means of creating wealth and transforming lives, especially for the poor people living in these countries. As the medicinal plants in use are neither classified as food or cash crops of health concern. Also no policy is in place to ensure the sustainability of traditional medicine and the protection of the environment.

This essay is focused on the role of medicinal plants in creating markets and transforming lives. In Nigeria so much emphasis has been placed on revenues generated from crude oil to the detriment of other revenue sources like herbal medicine.

Keywords Medicinal plants · traditional · medicine · resources · market · health and prosperity

1 Introduction

The WHO in its Alma-Ata declaration of 1978, gave due recognition to the role of traditional medicine(TM) and its practitioners (TMPs) in achieving comprehensive and affordable health care delivery, previously tagged "Health for all in the 21st century" although the situation remains "Health for some".

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Traditional medicine refers to health practices approaches, knowledge and beliefs incorporating plant, animal and mineral based medicines, spiritual therapies, manual techniques and exercises, applied singularly are in combination to treat, diagnose and prevent illness or maintain well-being. Traditional medicine which includes herbal medicine is also known as Complementary/Alternative medicine.

Traditional medicine plays a primary role in people's health, as they have for thousands of years there is a wide range of therapies and practices, varying greatly from country to country and from region to region. The most well known are the Ayurveda of India and traditional Chinese medicine and these systems of medicines have now spread to other countries.

Traditional medicine has always maintained its' popularity worldwide. For more than a decade, there has been an increasing use of traditional medicine (inform of complementary and alternative medicine) in most developed and developing countries.

2 Objectives

The objectives of this essay include the following:

- Provide information to economic and financial policymakers, the international financial community and/or international domestic investors on the huge economic opportunities that herbal medicine provides in Africa, particularly Nigeria, the most populous black nation in the world
- Provide insight into current Herbal Medicine Development (HMD) research in Nigeria which includes innovative and data-supported research resulting from the author's own professional and academic work
- Develop and support the implementation of leading-edge HMD initiatives that will ensure sustainable development
- Design a balance between conceptual and practical considerations for private-sector involvement in developing countries, and the effect of that involvement on development and the attainment of the Millennium Development Goals (MDGs) by the Nigerian government

The federal republic of Nigeria is situated along the golf of guinea, in the eastern part of the West African subcontinent. It extends over an area of 923,768 km^2 making it the tenth largest country in the world. Nigeria has a wide diversity of habitat, ranging from arid areas, through many types of forest, to swamps. Associated with the varied zones is an array of plant and animal species. The major vegetation formation are the mangrove forest and coastal swamps, fresh water swamps, low land rain forest, derived savanna, northern guinea savanna, Sudan savanna, Sahel, mountain, sub-montane forest and grassland.

In Nigeria, traditional medicine plays a significant role in meeting the health care needs of the majority of Nigerians. It also provides a livelihood for a significant number of people who depend on it as their main source of income, 75% to 80% of the Nigerian population uses the services of traditional healers (Federal

Government of Nigeria 2002).It can be extrapolated that 75% to 80% of Nigerians use herbal medicine because medicinal plants are the primary sources used by traditional healers in Nigeria (WHO 2006). The percentage could even be higher because almost all Nigerians eat herbal vegetables.

Several medicinal plants of global importance originate in the country. For example Calabar bean (Physostigma venenosum) was traditionally used in Nigeria as an "ordeal poison" in trials of wrong doers, from it the major component physiostigmine (eserine) and its derivatives, very important drugs have been discovered, and are now used against intra ocular pressure (glaucoma) (Landis 1996).

Nigeria has been ranked 11th in Africa for plant diversity. Out of the 5,000-plant species that exists in the country, 205 are considered endemic making the country the ninth highest among the 12 African countries in the level of endemic species (Ref FGN, 2002). With an estimated population of over 120 million people, distributed among over 250 distinct ethic groups or tribes, the country is unique in having high cultural diversity and a significant share of the global biological diversity.

3 Distribution of TMPs in Nigeria

In a study carried out by the author and her team in South West Nigeria 2005, the following results were obtained:

3.1 Methodology

Interviews and short questionnaires were used to elicit information from the practitioners. 126 practitioners were interviewed in three states Lagos, Ondo and Oyo states.

3.1.1 Results

One hundred and twenty-six questionnaires were distributed to TMPs in the South Western geographical zones of Nigeria comprising Oyo, Ondo and Lagos States. Sixty-eight percent of the respondents were men while 32% were women (Fig. 1).

4 Traditional Medicine Practices in Nigeria Include

4.1 Traditional Birth Attendants (TBAs)

Traditional delivery, obstetrics and gynecology are services rendered by traditional birth attendants in Nigeria. They are widely practiced in the rural and urban areas of

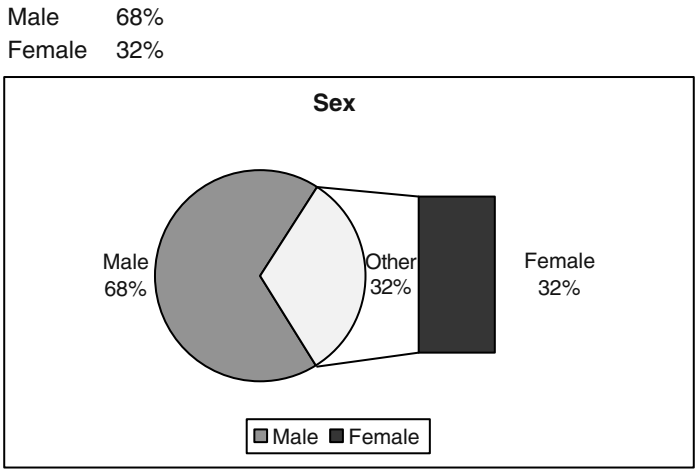

Fig. 1 Gender distribution of TMPs in Nigeria

the country and are highly patronized by our people due to increasing costs of health care in our conventional health institutions. Their positive contributions to health care delivery system can not be disputed. The services of traditional birth attendants are relatively cheap, readily accessible, personalized and does not carry out unnecessary surgery as a line of treatment, as practiced by conventional medical practitioners. However, this practice has to be improved upon.

The number of TBAs far out number that of their allopathic counter parts. The National Demographic and Health survey report (NDS 1999) indicate that only 37% of birth take place in conventional Health centers or hospitals. By inference 63% of Births are handled by Traditional medicine practitioner.

WHO seminars have recently highlighted the roles of TBAS in African society and many countries like Nigeria have arranged formal training in hygiene and obstetrics for these practitioners to improve their effectiveness. Some of the herbs used by TBAs include the root of *Carica papaya L.* chewed with seven seeds of *meleguata pepper* during labour, which is suppose to cause an immediate delivery of the baby. The bark of *Blighia sapida koeng* ground and mixed with locally made black soap is used for bathing through out the period of pregnancy. This ensures an easy delivery process for the pregnant woman (Sofowa 1982).Thus prevents surgeries.

4.2 Traditional Bone Setters and Massage Therapists

Traditional bone setting and Massage therapy are services rendered by traditional medicine practitioners and they are part of our culture and accumulation of our

peoples' experience in the management of fractures, pains and other related problems through the ages while making use of herbs. They need to be financially empowered in view of the immense contributions they make to the health care delivery system. There is no ailment known to man which nature has not provided remedy or cure for (WHO 2006).

Traditional bone setting is a specialized section of traditional medicine which uses;

- ➢ Fingers in the assessment of the extent of damage to a broken bone often without the use of x-ray.
- ➢ Application of herbal formulations to relieve pains.
- ➢ Application of local splint/caste to immobilize the bone in the management of fracture (WHO 2002, 2006), while traditional massage therapy is the application of gentle but firm pressure with the tip of the fingers and palms in order to relieve pain, stress, aching muscles, nerves, ligaments and tendons. Traditional bone setting and massage therapy are widely practiced in the rural areas due to their cheapness, availability and accessibility. They provide services that require no amputation as a line of treatment.

5 Global Market for Traditional Medicines

It is obvious that Traditional Medicine (TM) has maintained its' popularity in all regions of the developing world and its use is rapidly spreading in industrialized countries. Countries in Africa, Asia, and Latin America use TM to help meet most of their primary health care needs. In industrialized countries, adaptations of traditional medicines are termed "complementary" or "alternative" (CAM).

The global market for herbal medicines currently stands at over 60 billion US Dollars annually and is growing steadily (Federal Ministry of Science and Technology, 1985; Brevoort 1998). Nigeria like some other African countries with their vast bioresources and biodiversity are not making any contribution to the global market because the relevant stake holders are not showing enough interest to harness these vast resources to improve the lives of their citizens while creating markets. More than half of the populations live in poverty while these God-given resources waste away (Brinker 1998).

6 Sources of Medicinal Plants in Africa Include

- Home gardens and agricultural lands
- Botanic gardens
- Few proven cultivation practices for medicinal plants e.g. silviculture although this is minimal in developing countries although the potentials for this form of supply is enormous
- Traditional Medicine Practitioners also harvest from the wild e.g. natural forest remote and marginal lands

The result below was obtained from a survey conducted in South-south Nigeria and South-west Nigeria respectively in 2006 by the author on TMP's sources of medicinal plants:

South-south Nigeria		
Sources of herbs	Forest	45%
plant parts	Garden	24%
	Market	31%
Frequency of harvest	Daily	37%
	Weekly	48%
	Monthly	15%
South-west Nigeria		
Sources of herbs/plant parts	Forest	48%
	Home garden	15%
	Market	37%
Frequency of harvest of herbs	Daily	42%
	Weekly	46%
	Bi-monthly	7%
	Monthly	5%
Method of harvesting applied	Uprooting	30%
	Plucking/pruning	46%
	Debarking	24%

6.1 Current Herbal Medicine Development and Research

The government of Nigeria desires to maintain and encourage the growth and development of traditional medical practice through coordination and control.

These Government agencies like NAFDAC,NIPRID etc., NGOs and tertiary institutions work together, to facilitate national and international cooperative and collaborative research development and promotion effort in traditional medicines. They research, collate and document all traditional medicine practices and products in order to preserve the nation's positive indigenous knowledge on traditional medical science and technology development and promote safe, efficient traditional therapies and facilitate their integration into the national health care delivery system (Holmstedt 1972).

7 Accessing the Natural Medicine Market

The World Health Organization (WHO) estimates that one-third of the world's population has no regular access to essential modern medicines, in some parts of Africa, Asia, and Latin America, as much as half of the population faces these persistent shortages. However, in these same situations the rich resources of traditional remedies and practitioners are available and accessible.

7.1 Ways of Generating Income from Natural Medicine

7.1.1 Medicinal Plant Trade

An economic venture. The demand for products from the medicinal plants trade has been on the increase worldwide (Quansah 1998; Sergi and Kadriye 1995; Sofowa 2002). The trade so far relies heavily on wild collections to meet the ever-increasing demands. Nat Quansah reported that in Madagascar during 1996, one primary supplier earned 67.5 US Dollars for providing 225 kg of the raw material (raw plant) of *Sigesbeckia orientailis* to two sellers. These sellers sold the plant material to a total of 1,500 people and made 450 US Dollars. Thus, 225 kg of *Sigesbeckia orientialis* yielded 517.5 Dollars in a market. Also the market value of 399,447 kg of 11 species of medicinal plants and/or their extracts in 1995 was estimated at 1,382,000 US Dollars. Nigerian plants such as the *Ocimum spp., Vermonia amygdalina, cympopogon citratus* have great marketing potentials because of their multipurpose uses as spices, ornaments, medicines etc.

7.1.2 Horticulture and Perfumery

African plants are valued ingredients but have been traded only at the lower end of business, for example, many Africa pelargonium species are offered for sale in other countries. Revenue generated from the sales of pelargonium species in Belgium, Netherlands and Germany approximately 6 billion US Dollars annually (Rosonaivo 1996).

7.1.3 Pharmaceuticals

The array of medicines derived from plants is impressive – analgesics, diuretics, laxative, anti-cancer and anti-parasitic components, cardiovascular, anti-inflammatory and anti-viral drugs, just to mention a few. It has been estimated that as many as 75% to 90% of the worlds rural people rely on herbal traditional medicine as their primary health care (WHO 2006) and this is a source of incomer for the growers such plants and practitioners. African flora is potential for new compounds with pharmacological activities. Such efforts have led to the isolation of several biologically active molecules that are in various stages of development as pharmaceuticals.

7.1.4 Cultivation

The time has come for economic & financial policymakers, the international financial community and/or international domestic investors to start large scale cultivation of medicinal plants especially those with proven efficacy and safety. Most of these plants grow well even on deteriorating soil.

To ensure the production of standard plant drugs with acceptable quality, uniformity and purity, factors such as, sources and identity of the plant, its physical characteristics, its chemical constituents, the pharmacological and biological activities of the crude drug and method of preparation, uses and storage, amongst others, need to be identified and documented.

8 Drawbacks of Herbal Medicine Markets in Africa (Nigeria)

Drawbacks to our traditional medicine heritage and medicinal plants that can serve as raw materials for traditional and modern drug production:

- Rapid destruction and degradation of our environment
- Loss of useful medicinal plant species
- The passing away of the custodians of knowledge on our medicinal plants
- The lack of documentation of our medicinal, aromatic and pesticidal plants and traditional medical knowledge

9 The Steps Forward

Careful identification and documentation of an inventory of Nigeria's Medicinal Plants, their usefulness and the knowledge base for their utilization amongst other factors is expedient. An inventory/database on available plant raw materials, among others, should be available. These will stimulate the processes for the development of legislative and administrative framework for their conservation and as raw materials for exploitation.

10 Conclusion

In order to effectively protect the environment, there is need for government to recognize and formulate policies ensure the uniformity of herbal medicine practices. Factors such as, sources and identity of the plant, physical characteristics, chemical constituents, the pharmacological and biological activities of the crude drug and method of preparation, uses and storage, amongst others, need to be identified and documented.

The development of herbal medicine will create markets and ultimately improve the lives of the people who depend on it as a source of livelihood; the Traditional Practitioners, the cultivators/gatherers, the market women (hawkers), the manufacturers of packaging materials, increase the income generated by the government and attract foreign investment. It will also contribute positively to the attainment of a befitting primary health care for the citizenry.

References

Brevoort, P. 1998. The booming US botanical market: A new overview. Herbal Gram 44:33–48.
Brinker, F. 1998. Herb contraindications and drugs interactions. Sandy, OR: Eclectic Medical Publications.
Federal Government of Nigeria. 2002. National biodiversity strategy and action plan Abuja. Government Press 2–7
Federal Ministry of Science and Technology, Federal Republic of Nigeria. 1985. Report of the national investigative committee on traditional and alternative medicine, Abuja. Government Press.
Federal Ministry of Health, Nigeria Demographic and Health Surveys, 1999.
Holmstedt, B. 1972. The ordeal bean of old Calabar; the pageant of physostigma venonosum in medicine. Swain Ted. Plants in the development of modern medicine. Cambridge, MA: Harvard University Press, pp. 303–360.
Landis, P. 1996. Market report. Herbalgram 36:69. American Botanical Council and the Herb Research foundation USA.
Quansah, N. 1998. Medicinal Plants: A Global Heritage 16: 160. Proceedings of the International Conference on Medicinal Plants for Survival.
Rasoanaivo, P. 1996. Plantes Medicinales et Aromatiques a Valeur economiques a Madagascar.
Sergi, H. and Kadriye, T. 1995. The strength and weakness of Turkish bone setters. World Health Forum 16(2) 203–205.
Sofowa, A. 1982. Medical plants and traditional medicine in Africa. Wiley.
World Health Organization. 2002. Traditional medicines – Growing Needs and Potential. WHO policy respective on Medicine, Geneva (WHO/EDM/2002. 4).
World Health Organization. 2006. WHO report on traditional medicine, my documents/WHO traditional medicine.htm 15/06/2006.

Microbial Risk Assessment: Application and Stages to Evaluate Water Quality

M.T.P. Razzolini, W.M.R. Günther, and A.C. Nardocci

Abstract This works presents the stages of microbial risk assessment and its application in the evaluation of drinking and recreational water quality and further the risk of diseases attributable to pathogens present in these waters. In Brazil, infectious diseases were responsible for 5.1% of deaths, the fifth place of mortality cause. Most affected people are children, elderly and immunocompromised population. According to Brazilian Health Ministry, from 1995 to 1999, environmentally-caused diseases occupied 3.4 million beds in hospitals. All of these reports showed a very public health concerning scenario.

This tool can provide bases to establish tolerable (acceptable) risk and thus defining the protection level to human health for each hazard, in this case, pathogens microorganisms. The stages are hazard identification, exposure assessment, dose-response relationship and risk characterization. The hazard identification is related to the presence of microorganism and toxins and their association with specific diseases. The exposure assessment includes the intensity, frequency and duration of human exposure to a specific agent. The aim of dose-response relationship is to acquire a mathematical relation between amount of microorganism (concentration) and adverse effect on human health. Risk characterization represents the integration of the previous stages. Risk assessment is a tool used for decisions making and providing information to take measures of control and interventions, as well as to evaluate the impacts of these actions. It provides support to a decision-making process based on scientific results in several areas of the knowledge. In Brazil, risk assessment is a recent area of research, but promising for the management of water's quality such as catchments points and recreational waters, in special in periurbans areas of metropolitan regions, which show precarious sanitary conditions.

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Keywords Microbial risk assessment · water quality · risk management

1 Introduction

In recent years it has been observed that an increasing number of waterborne outbreaks have occurred due to water resource contamination by sewage and solid waste that carry pathogenic microorganisms. These microorganisms do represent a public health concerning which of them can survive long enough to cause human health disturbs. Out of them, emerging and reemerging pathogens deserve special attention. According to World Health Organization, in developing countries it was estimated that 94% of the diarrhea burden of disease is attributable to environmental and associated with risk factors such as unsafe drinking-water and poor sanitation and hygiene, on average, children in developing countries lose eight-times more healthy life, per capita, than their peers in developed countries from environmentally-caused diseases. Infectious diseases which contributing to the environmental burden of disease among children from 0 to 14 years old are intestinal nematode infections (1.5%) and diarrhea disease (29%) (WHO 2006). Bartram (2006) reported that 1.8 million people, mostly children, die of diarrhea every year. In Brazil, infectious diseases were responsible for 5.1% of deaths, the fifth place of mortality cause. Most affected people are children, elderly and immunocompromised population. According to Brazilian Health Ministry (Brasil 2004), from 1995 to 1999, environmentally-caused diseases occupied 3.4 million beds in hospitals. All of these reports showed a very public health concerning scenario.

According to Hass et al. (1999), the preventing of infectious diseases transmission from human exposure to contaminated food, water, soil and air remains a major role of environmental and health professionals. In this way, microbial risk assessment is a very useful tool to evaluate drinking and recreational water quality, applying it and further to determine the risk of diseases attributable to pathogens present in waters sources. Besides, this tool can provide bases to establish tolerable risk and thus defining the protection level to human health for each hazard, in this case, pathogens microorganisms. Establishing tolerable risk is an important issue to be considered because of the risk perception occurs in different ways dependable on affected people, magnitude of the adverse effects, how people are habituated to face the adverse effects and amount of people affected (Peña et al. 2001), moreover this perception can be diverse by the general population, politics, researches and managers. Undoubtedly, microbial risk assessment allows an improvement in the capacity to evaluate and control the risks as well as in the making-decision process to minimize risks as choosing the best sanitary barriers option. Acquiring all this knowledge would be an advance to protect human health, mainly in developing countries where there are many areas with evident environmental vulnerability.

The goal of this work is present the stages of microbial risk assessment and its application in the evaluation of drinking and recreational waters quality.

2 Microbial Risk Assessment Application

Risk assessment process consists of estimating the probability that an event can occur and the probable magnitude of its adverse effects (Gerba 2000). In relation to microbial risk assessment, it can be said that it is a process which evaluate the probability of an adverse effect on human health after exposure to pathogenic microorganisms or contact with a source (water, soil, air, food) with pathogens presence as well as their toxins. The advantages of using this kind of analysis is estimate the results of exposure to infectious microorganisms as well as express it quantitatively in terms of probability of infection, morbidity (disease) and/or death. With these results is possible to do prevision about the expected number of infectious diseases, diseases and fatalities due of a determined exposure. In addition, microbial risk assessment can provide bases to establish tolerable risk and thus defining the protection level to human health for each relevant pathogen.

United States Environment Protection Agency (US EPA), due to occurrence of waterborne infectious agents in surface waters catchments points such as *Giardia* cysts and enteric viruses developed the Surface Treatment Rule (STR). The STR, based on microbial risk assessment, required that all drinking water plants be capable of removing 99.0% of *Giardia* cysts and 99.9% of enteric viruses, to get to the infection tolerable risk because of these etiologic agents was not superior to 1 per 10,000 exposed persons annually (10^{-4} per year) (Gerba 2000). The same approach can be transferred to other sort of waters as recreational or else wastewater with potential reuse.

World Health Organization (WHO) in the latest publication of Guidelines for drinking water quality and Guidelines for recreational waters environments – Coastal and Freshwaters, consider microbial risk assessment as a way to estimate risks to human health related to microbiological quality of drinking and recreational waters as well as permit to translate risk of developing a specific illness to disease burden per case expressed in DALY (Disability-adjusted life-year) (WHO 2004). It is interesting for the reason that it allows to compare severity among diseases and microbial agents.

3 Microbial Risk Approach

Microbial risk assessment is characterized by a framework which consists of problem formulation and hazard identification, exposure assessment, dose-response assessment and risk characterization. Each component aims to characterize the entire scenario and its impact of human health as shown in Fig. 1.

Accordingly Soller problem formulation involves all stakeholders and its point is to identify the purpose of the risk assessment, critical issues and the treatment of the obtained results to protect public health (Soller 2006).

Identifying hazard is a step that consist of acquiring information from clinical studies and epidemiological and surveillance studies. All aspects to lead to potential hazards reach drinking and recreational waters and furthermore human being affecting their health condition should be considered. This information

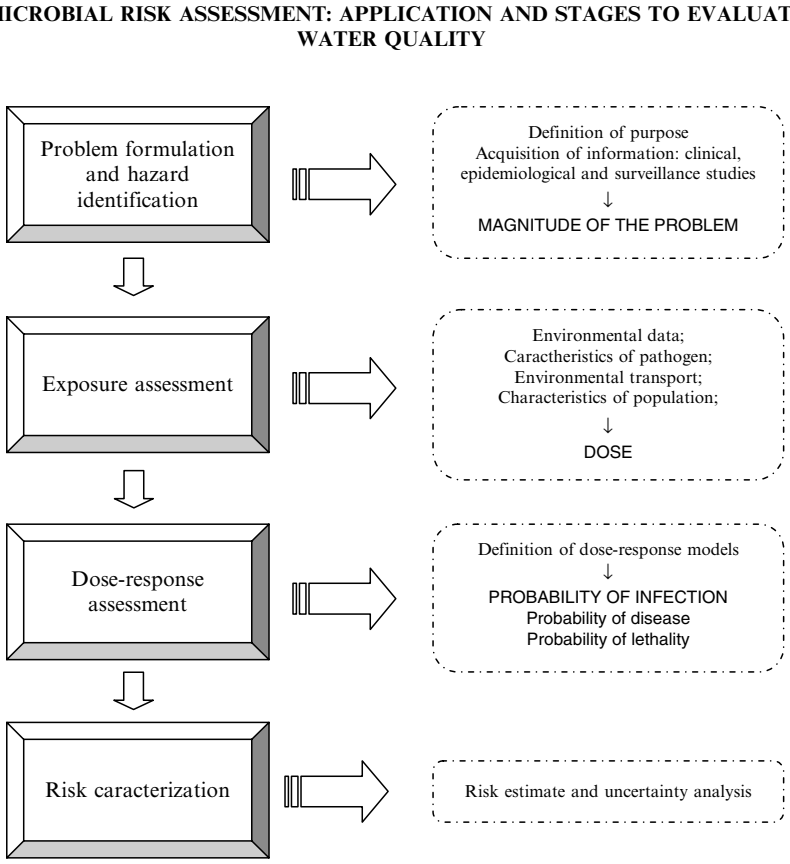

Fig. 1 Microbial risk assessment approach

gives the magnitude of the problem and how it impacts affected population health. It is not easy to do because a part of affected population does not look for medical attention for several reasons (mild symptoms or difficulty medical accesses, for instance), asymptomatic persons occurrence, unsatisfactory register data as source of infection and infectious agent, inappropriate pathogen method detection, medical attendance quality discrepancies among different areas around the country and some times microorganism infectivity and lethality are not clear.

The exposure assessment refers to the measure process or intensity, frequency and duration of human exposure to a specific infectious agent. It is used to estimate the microorganism concentration which is corresponding to a single exposure or a total of organisms in a set of exposures (Haas et al. 1999; Gerba 2000). The exposure can happen via inhalation, ingestion of water or food or dermal. In this step is important to consider the population affected, real or

potential, and the contamination sources as well as transport mechanisms and biotransformation and moreover all pathogenic microorganism pathways until reach its host including ingress via. In this case, the amount of drinking water is daily ingested or volumes ingested of water during recreation in swimming pools or beaches for that reason regional ingestion water data is important to conduct the exposure assessment.

Dose-response assessment is a result from experimental studies to develop a relationship between the level of microbial exposure and the likelihood of occurrence of an adverse consequence (Haas et al. 1999). These data are currently available for waterborne pathogen from studies using healthy adults volunteers (Gale 2001) to identify the infectivity to specific pathogens, on the other hand there are not studies with more susceptible population such as children, elderly, immunocompromised. The consequences from an infection process are highlighted: (a) asymptomatic illness, (b) acute symptomatic illness – mild to moderate symptoms, days loss from work and heath care cost and (c) chronic infections as, for example, hemolytic uremic syndrome or stomach ulcers. Dose-response models should approach the probability of infection as well mortality probability. Even though, in some cases data about pathogens infectivity are not available so mathematical models are useful to estimate dose-response relationship such as Poisson distribution and Exponential distribution as shown in Table 1.

Risk characterization integrates all information acquired in previously steps – problem formulation and hazard identification, exposure assessment and dose-response relationship –to calculate the probability of infection of the exposure by drinking and or recreational waters contaminated with pathogens. Besides that, this stage consists of uncertainty evaluation and risk communication.

In addition, the quantitative risk estimate is useful to obtain a burden disease expressed by DALYs (Disability-adjusted life-year). In countries such as Brazil, with so difference in socio-economical and sanitary conditions among its regions the DALYs calculating is interesting to give the adequate significance for each burden disease in specific areas avoiding distortions. It has a special meaning to risk management phase when financial support should be addressed and public policies elaborated to improve waters sanitary quality.

Table 1 Dose-response parameters for pathogen ingestion mathematical models studies (adapted from Gerba (2000))

Microorganisms	Best mathematical model
Echovirus 12	Beta-Poisson
Rotavirus	Beta-Poisson
Poliovirus 1	Exponential/Beta-Poisson
Poliovirus 3	Beta-Poisson
Cryptosporidium	Exponential
Giardia lamblia	Exponential
Salmonella	Exponential
Escherichia coli	Beta-Poisson

4 Final Considerations

In Brazil, microbial risk assessment is a recent area of research, but promising for the management of water's quality such as catchments points and recreational waters, in special in periurbans areas of metropolitan regions, which show precarious sanitary conditions that lead a high waterborne diseases incidence. In Brazil and others developing countries microbial risk assessment is useful to allow to maker decision to define more realistic goals to these poor areas considering not only minimizing risk but to evaluate benefit-cost of intervention actions.

On the other hand, developing countries present limiting structure to implement microbial risk assessment such as lack of truthful data and specific data for each studied area. It should be highlighted in view of applying imported information or models from others countries can increase the uncertainties and impair the use of this tool.

To sum up, it should be emphasized how important is the criteria flexibility in decisions demand institutions with political powerful and technically well prepared. In developing countries these aspects do not happen very often.

References

Bartram, J. (2006) Water, health and the millennium development goal. In: IWA World Water Congress. 10–14 September 2006, Beijing, China.

Brasil (2004) Ministério das Cidades. Saneamento Ambiental 5. Cadernos MCidades Saneamento Ambiental. Brasília.

Gale, P. (2001) A review – developments in microbiological risk assessment for drinking water. J Appl Microbiol, 91, 191–205.

Gerba, C.P. (2000) Risk assessment. In: Maier, R.M., Pepper, I.L., and Gerba, C.P. (Eds) Environmental Microbiology. San Diego, CA: Academic Press, pp. 557–570.

Haas, C.N., Rose, J.B., and Gerba, C.P. (1999) Quantitative Microbial Risk Assessment. 1st ed. New York: Wiley.

Peña, C.E., Carter, D.E., and Ayala-Fierro, F. (2001) Evaluación de Riesgos y Restauración Ambiental. Southwest Hazardous Waste Program – a Superfund Basic Research and Training Program at the College of Pharmacy, The University of Arizona.

Soller, J.A. (2006) Use of microbial risk assessment to inform the national estimate of acute gastrointestinal illness attributable to microbes in drinking water. J Water Health, 4(2), 165–186.

WHO (World Health Organization) (2004) Guidelines for drinking-water quality. Volume 1 – Recommendations. 3rd ed. Geneva.

WHO (World Health Organization) (2006) Preventing disease through healthy environments – Towards an estimate of the environmental burden of disease. Executive summary.

Benefits and Dangers of Nanotechnology: Health and Terrorism

Y.A. Owusu, H. Chapman, T.N. Dargan, and C. Mundoma

Abstract The first goal in this paper is to discuss the fundamental principles, applications, advantages, and disadvantages of nanotechnology with a view of promoting the importance and validity of nanotechnology in the developed countries as well as the emerging developing countries in Africa and elsewhere. The second goal is intended to provoke critical thinking, analysis, medical applications, environmental and economic issues or implications involving nanotechnology. The third goal is to discuss the potential security threat that would pose world peace, should nanotechnology, nanodevices, nanomaterials fall into the wrong hands.

Keywords **N**anotechnology · quantum dots · nanites · United Nations · cancer

1 Introduction

The discoveries in the field of nanotechnology of its existence and applications over the past four decades are staggering. If the dream of a nanoage is within two decades according to nanotechnology prognosticators, then life as its known today will be changed forever. The science of manipulating matter at its most fundamental level, atoms and molecules, would be the discovery of the millennium. The National Science Foundation (NSF) of the United States of America is massively funding research in nanotechnology. Neal Lane, Director of NSF, said: 'If I were asked for an area of science and engineering that will most likely produce the breakthroughs of tomorrow, I would point to nanoscale science and engineering, often called simply *nanotechnology*.' Nano is a one billionth unit of measurement and derives from the Greek word for dwarf. The

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focus of nanotechnology ranges from developing nano-sized chips for supercomputers to engineering molecular robots (nanorobots) that perform specific functions.

More specifically, nanotechnology deals with the creation of functional materials, devices and systems through the control of matter and exploitation of novel phenomena and properties on nanometer scale (Merkle 1992). For an example, if atoms are re-arranged in coal, that structure converts itself into a diamond. Also, if the atoms that are found in sand are re-arranged and added a few other elements, that structure becomes computer chips or solar panels. Of particular significance is the emerging field of nanotechnology-based biomedical techniques.

2 Medical Applications of Nanotechnology

For many different reasons, there has been great effort to improve and discover new manufacturing processes, products, and systems, which will aid physicians to treat and prevent asthma, cancer and other chronic diseases. As far fetched, as this may seem, this is what has been discussed in this paper: the application of nanotechnology for the treatment and prevention of chronic diseases, such as asthma and cancer. Two main applications are presented.

2.1 Application of Gold Nanoparticles (GNPs) Used as Biomarkers for Detecting Metastasis of Cancer Tumor

Due to their biocompatibility and excellent optical properties, gold nanoparticles are finding increasing application in a variety of areas including DNA detection and cancer diagnostics. The gold nanoparticles can be conjugated to an antibody for epidermal growth factor receptor (EGFR) proteins. These EGFR cells which are found on the surface of most cancer cells respond to the presence of gold due to the ability of the gold nanoparticles to absorb light. Figure 1 shows the optical effect of gold nanoparticles on cancer cells due their high affinity for cancer cells. In addition to these developments, colloidal gold nanoparticle platforms have been designed and used as a tumor targeting ligand and a cancer therapy (Paciotti et al. 2005). A new synthesis has been developed for the tumor-associated, cell-surface carbohydrate moiety, known as the Thomsen-Friedenrich antigen (T-antigen) (Svarovsky et al. 2005).

2.2 Use of Nanoparticles (I.E.: Quantum Dots) to Aid in Imaging of Cancer Cells for Site-Specific Drug Delivery

A variety of nanomaterials are finding viable applications including drug delivery as well as targeting and imaging of the onset of malignant tumor formation in tissues (Owusu and Owusu 2000). It is estimated that the global market for drug

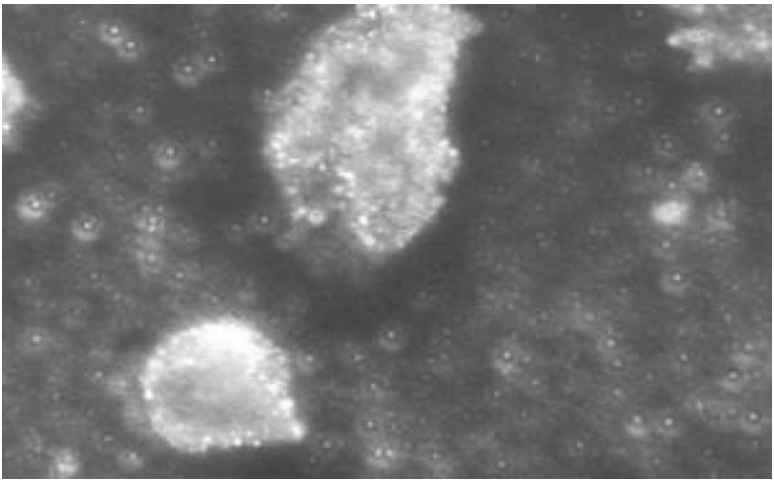

Fig. 1 SEM image showing the high affinity of gold nanoparticles for cancer cells. The gold nanoparticles stick to cancer cells and make them shine (El Sayed 2005)

delivery products is $33 billion per year and growing at a rate of 15% per year (Hill 2005). Recent studies have suggested that nanoparticle drug delivery might improve the therapeutic efficacy of anticancer drugs and allow the simultaneous monitoring of drug uptake by tumors (Kukowska-Latallo et al. 2005). Research in the design and applications of semiconductor nanocrystals, known as Quantum Dots (QDs) is gaining prominence. Quantum dots are the nanoparticles that are recently emerging as an alternative to organic fluorescence probes in cell biology and biomedicine. QDs are monodispersed semiconductor nanocrystals (size range: 2–10 nm) covered with a stabilizing monolayer. QDs have several predictive advantages such as ability to absorb light within a broad band of wavelength but emit at much narrower bands. QDs have high stability, and possess superior imaging capabilities. These unique properties allow simultaneous excitation of different sizes of quantum dots with a single excitation light source with simultaneous resolution and visualization as different colors (Fig. 2). In the area of biomedical applications, water-soluble and biodegradable QDs that have been encapsulated with glycopeptides in the form of receptors and ligands have been shown to bind to living cells (Loo et al. 2004). Recently, highly luminescent encapsulated quantum dots with cadmium tellurium (CdTe) core structure (Fig. 3) have been synthesized in a one-pot aqueous synthetic method (Svarovsky et al. 2005).

The goal of this current research work is to exploit the luminescence properties of QDs to aid in imaging for identifying cancer cells for site specific drug delivery. T-antigen bearing quantum dots are used to locate small metastasis in the midst of normal tissue. In addition, QDs can significantly improve clinical diagnostic tests for the early detection of malignant tumors. Encapsulated QDs

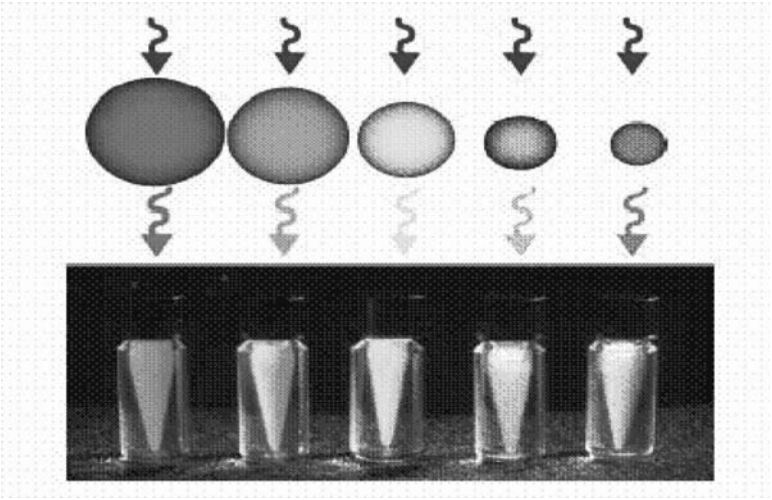

Fig. 2 Schematic representation of the effect of size on the color of QD particles (Five different QD solutions can be excited with a single wavelength)

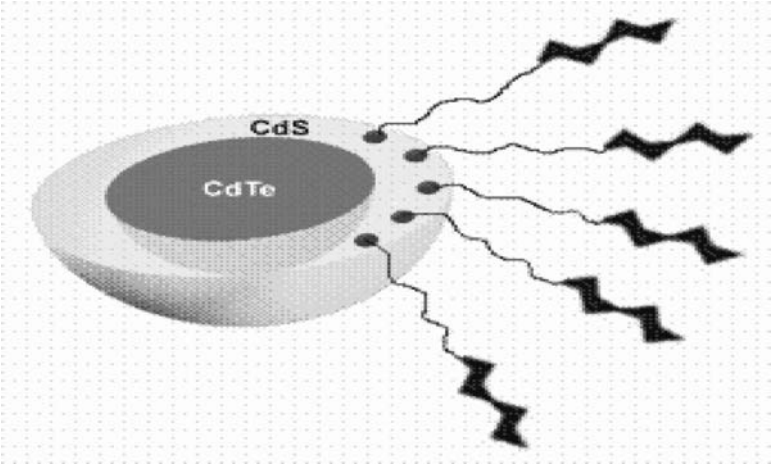

Fig. 3 Quantum Dot structure showing CdTe core and cds shell formation. The linkers are the ligand attachments (Svarovsky et al. 2005)

can be used to identify disease markers similar to currently widely used Magnetic Resonance Imaging (MRI).

Of particular significance is the emerging field of nanotechnology-based biomedical techniques. Nanoparticle-based techniques are promising novel tools that present the ability for earlier, faster and more selective diagnosis of cancer at much lower costs and reduced side-effects than traditional methods.

2.3 Nanoparticles for Malignant Tumor Diagnostics and Drug Delivery

A variety of nanomaterials are finding viable applications in the area of targeting and imaging of the onset of malignant tumor formation in tissues. The targeting capability of nanoparticles is influenced by particle size, surface charge, surface modification, and hydrophobicity whilst their general performance in vivo is influenced by morphological characteristics, surface chemistry, and molecular weight. Nanoparticles can be designed for site-specific delivery of drugs since they act as potential carriers for several classes of drugs such as anticancer agents and antihypertensive agents.

2.4 Design and Synthesis of Gold Nanoparticles

Due to their biocompatibility and excellent optical properties, gold nanoparticles are finding increasing application in a variety of areas including DNA detection and cancer diagnostics. They are also useful for identification of protein-protein interactions (Salata 2004). Gold nanoparticles functionalized with oligonucleotides have been used as probes in DNA detection (Daniel and Astruc 2004). The gold nanoparticles can be conjugated to an antibody for epidermal growth factor receptor (EGFR) proteins. These EGFR cells which are found on the surface of most cancer cells respond to the presence of gold due to the ability of the gold nanoparticles to absorb light. The gold nanoparticles display a much higher efficacy. QDs acting as multivalent fluorescent tags (Fig. 4) can be used to seek out specific lectins and antibodies in a multiplex fashion to detect various disease states or harmful pathogens simultaneously in high throughput for medical diagnostics. Small spherical particles of average diameters between 5 and 20 nm have been prepared by UV radiation of gold ions. Larger particles (20–110 nm) have been formed by irradiation coupled by reduction with absorbic acid (Sau et al. 2001). Figure 5 shows schematic representation of protein complexes formation in relation to cell genomics. Figure 6 shows the effect of gold nanoparticles (GNPs) on lung specimens compared with treatment with phosphate buffered saline (PBS) solution. Those treated with GDPs look better than those treated with PBS (as shown in Fig. 6).

2.5 Expected Outcome, Intellectual Merit, and Broader Impact of Current Research

It is envisioned that quantum dots and gold nanoparticles sensors outlined in this paper would:

- Improve sensitivity and selectivity of nanosensors in targeting of Epidermal Growth Factor Receptor (EFGR) proteins commonly present at the surface of most cancer cells (since EFGR proteins are at the same molecular level as the cancerous cells)

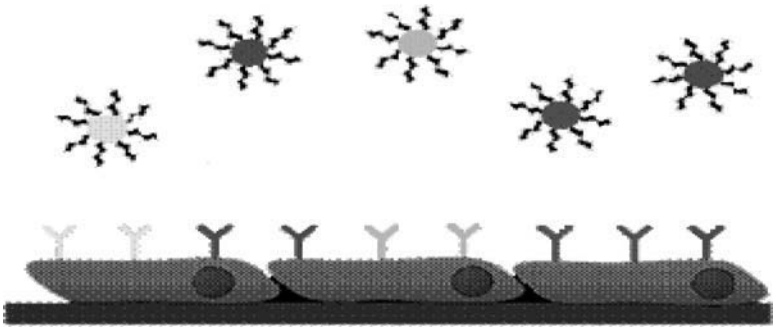

Fig. 4 The multivalent fluorescent tagging property of quantum dots (QDs)

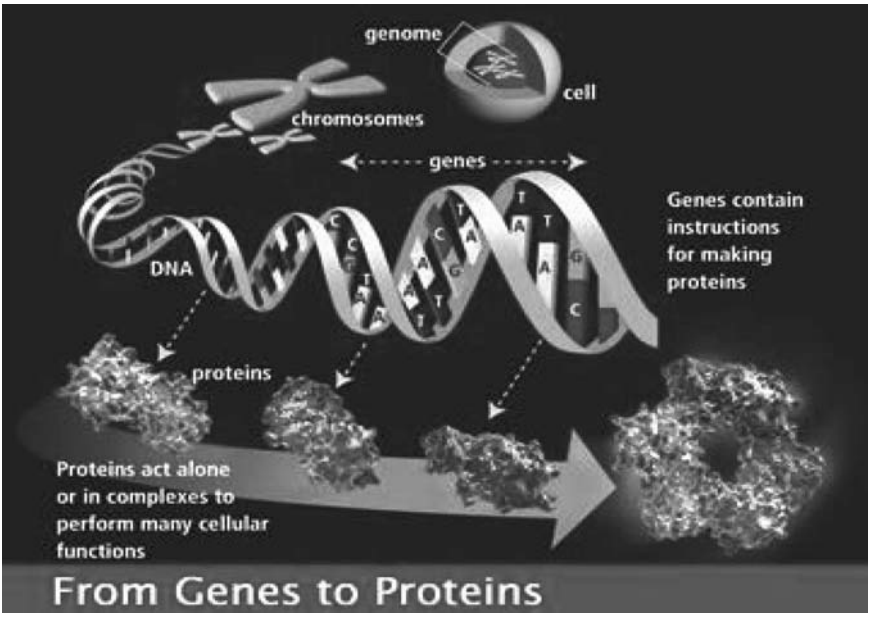

Fig. 5 Schematic representation of protein complex formation in relation to cell genomics (U.S. Department of Energy Human Genome Program, Available at: http://www.ornl.gov/hgnis, 2008)

- Lead to a more effective screening and detection of cancerous tumors
- Improve selectivity of drug injection into individual cells

It is likely that this advanced technology will soon result in rapid and widespread introduction of manufactured nanomaterials and devices into commerce.

The progress in this research endeavor is expected to uniquely and substantially enhance our capability in our efforts toward the development of nanorobotic devices (Owusu et al. 2006) that will be programmed to mitigate against the growth

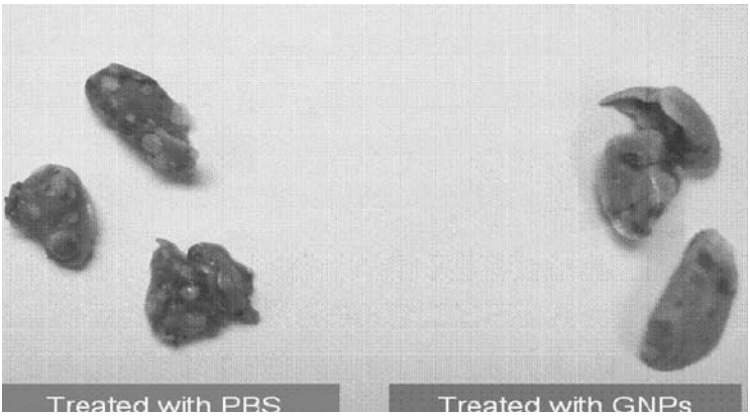

Fig. 6 Comparison of lungs treated with phosphate buffered saline (PBS) solution (left) and gold nanoparticles, GNPs (right)

of malignant cells in the human body that are responsible for diseases like cancer, asthma, etc. The expected outcomes outlined above coincide with the research goals of Research Center for Cutting Edge Technologies (RECCET) aimed at providing positive implications to the human interface between incurable diseases and nanotechnology (Owusu and Owusu 2000). The set-up in Fig. 7 is to aid in generating ultra-violet radiation for fabrication of nanosensor particles by the authors of this paper at the Research Center for Cutting Edge Technologies (RECCET) in Tallahassee, Florida, USA. This is a small portion of an elaborate experimental set up and sophisticated equipment servicing the Research Center.

2.6 Real World Applications of Nanotechnology in Medical Field

This is a proposed structure of a simple nano robot and diamondiod sphere for selective transport method as envisioned for controlled release of oxygen by Drexler (1992) in Figs. 8 and 9, respectively (1992). The concept in Figs. 10 and 11 will help to mitigate heart attacks and strokes by pumping oxygen to where it is needed during an attack or stroke.

2.7 Simulation of Selective Oxygen Nanotransport Device (SOND)

Nanodevices can be of great use in the medical field just for the purpose of preserving human life. Nanodevices are on the scale in which all things are created, there by, have the ability of accomplishing feats that no drug itself can do. This is due to

Fig. 7 Solar simulator and its controls along with the electrometer at Research Center for Cutting Edge Technologies (RECCET)

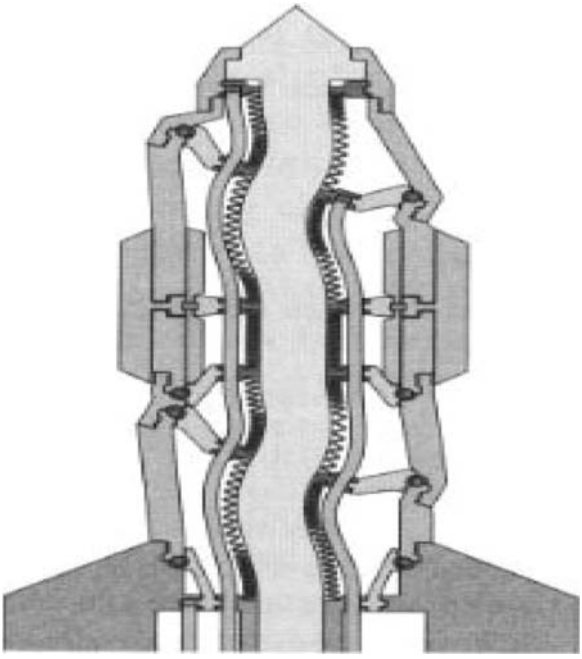

Fig. 8 Robotic device (Drexler 1992)

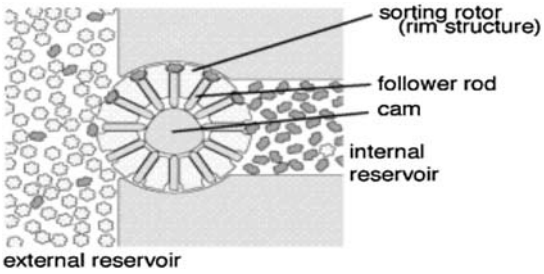

Fig. 9 Selective transport method (Drexler 1992)

the fact that nanodevices are extremely precise. In fact, nanodevices have the ability to form a structure whether living or nonliving, atom by atom. With this level of precision, nanodevices will not only be able to cure, but will also be able to prevent diseases. Specifically, a nanodevice such as Oxygen Nanotransport Device being developed at the Research Center (RECCET) by the authors of this paper can be used to prevent horrible medical ailments such as heart attacks, aneurism, and strokes. Heart attacks, aneurism and strokes are caused by the lack of oxygen going to the heart and/or the brain. Schematic views of the Selective Oxygen Nanotransport Device (SOND) combined with the artificial holding reservoir are shown in Figs. 10 and 11. The device can collect and redistribute oxygen in the blood stream in order to prevent abnormally low levels of oxygen or shortage of oxygen in the blood stream to the brain and/or the heart.

3 Terrorism Issues of Nanotechnology

The purpose of the following sections is to discuss the potential dangers and security threats that may be posed to world peace should nanotechnology materials and devices fall into the wrong hands for the purpose of terrorism and domination of world power. The role of the United Nations Regulatory Committee, as a watchdog for monitoring the use of nanotechnology, is also discussed.

3.1 The Right Tools in the Wrong Hands

Like computers, nanotechnology and programmable assemblers could become ordinary household objects. It is not too likely that the average person will get hold of and launch a nuclear weapon, but imagine a deranged person or a terrorist launching an army of nanorobots programmed to kill anyone with brown eyes and curly hair or people with blue eyes and straight hair. Even if nanotechnology remains in the hands of governments, think what a Stalin or a Hitler could do or few

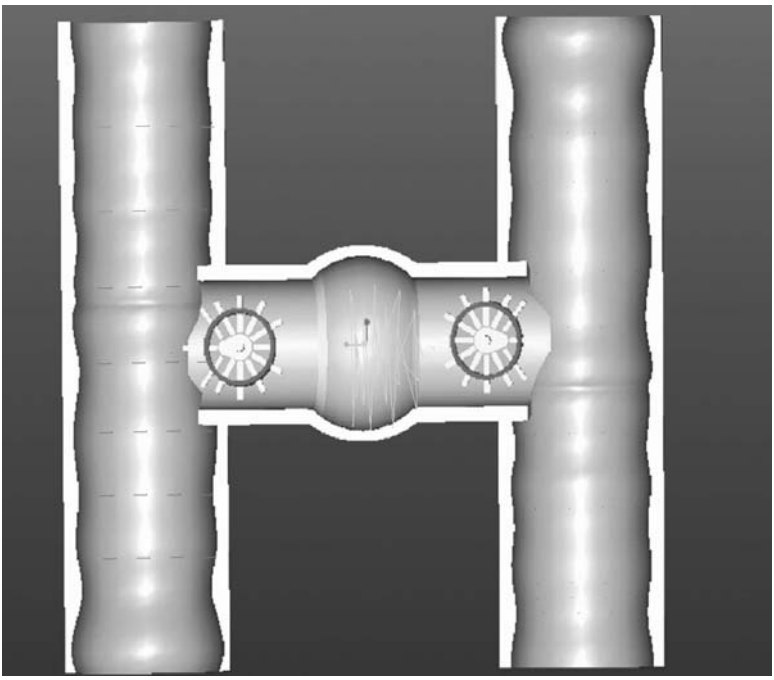

Fig. 10 The oxygen nanotransport system (SOND) and arteries in human body

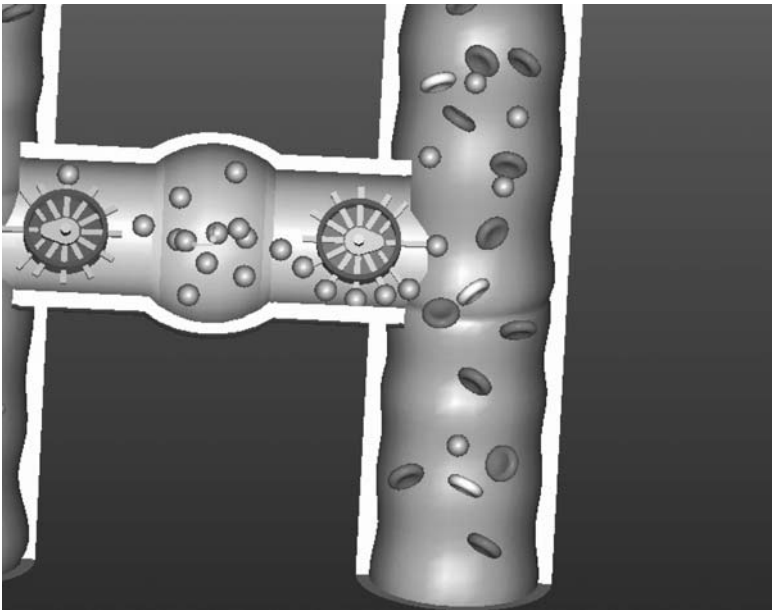

Fig. 11 Lack of oxygen in the right artery shows the SOND on the right releasing oxygen molecules (ball shaped particles)

countries will lord over other countries (as it is currently with nuclear weapons). Vast armies of tiny specialized nano killing machines could be built and dispatched in a day. Nano-sized surveillance devices or probes could be implanted in the brains of people without their knowledge.

3.2 Potential Threat of Bio-terrorism

The most serious aspect of the down side of nanotechnology, yet, is the potential threat of bio-terrorism. Matter is being manipulated at its most fundamental level, and this is the level at which diseases could be manufactured. Trillions of deadly, poisonous, and infectious nanites (nanorobots) could be manufactured in a nano-laboratory and be released on a sector of humanity wiping out whole populations, should this technology fall into the hands of terrorist organizations or some power seeking countries.

3.3 Role of United Nations for Nanotechnology Security Around the World

It is with this in mind that the authors of this paper feel strongly that the need for a world governing body or regulatory organization on nanotechnology is imperative. This proposed body, formed, constituted and run by the United Nations will focus its energies on the down side of nanotechnology. Figure 12 shows a proposed organizational chart of what such a body will look like. It is in this vain that the proposal to establish this International Steering Committee on Nanotechnology (ISCON) as a governing body to regulate the development, deployment, and the use of nanotechnology is of utmost importance. The governing body should take the form of a Committee of the United Nations and will comprise members from developed as well as developing countries. Lawyers, Doctors, Scientists, the Clergy as well as Government appointed officials will form the core of such a committee with 12 members; and each being also an active member of a sub-committee responsible for different aspects of the regulatory function. The chairperson of this committee will be appointed every 4 years by the United Nations Security Council and will report directly to the office of the United Nations (UN) Secretary General.

It is not the purpose of the authors of this paper to dampen the natural initiatives, innovations, and discoveries in this field; but one cannot over emphasize the need to keep this potentially deadly form of technology from falling into the wrong hands. Nanotechnology must be seen as one of the tools of science, engineering, and technology to foster a sense of brotherhood, goodwill, and peace among nations while forging greater ties among peoples, rather than for destructive means.

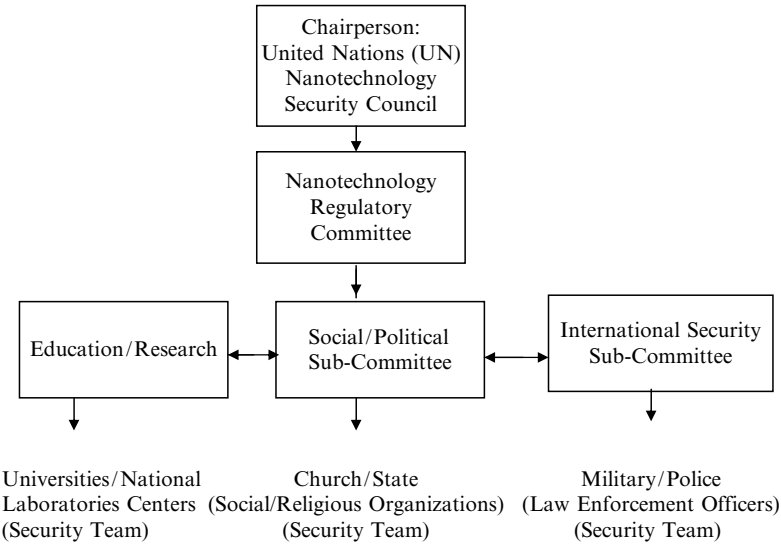

Fig. 12 Proposed organizational chart of United Nations Regulatory Committee on nanotechnology and its applications

4 Concluding Remarks

It is not a matter of if, but when nanotechnology becomes a household application. The nanoage is here and it will revolutionize the status quo on planet earth, including its International Security Profile. Had Albert Einstein foreseen the use to which his relativity theory would have been put in 1945, in Hiroshima, Japan, he probably would have had second thoughts about the way he disseminated his discoveries.

As General Douglas Macarthur said in his farewell speech before a joint sitting of the US Congress after the end of World War II on April 19, 1951:

> Men since the beginning of time have sought peace. Various methods through the ages have been attempted to devise an international process to prevent or settle disputes between nations. …. We have had our last chance. If we will not devise some greater and more equitable system, our Armageddon will be at our door. The problem basically is theological and involves a spiritual recrudescence, an improvement of human character that will synchronize with our almost matchless advances in science, art, literature, and all material and cultural developments of the past two thousand years. It must be of the spirit if we are to save the flesh.

We need to heed General Macarthur's warning and learn from the lessons of history and use nanotechnology solely for peaceful means.

References

Daniel, M.-C. and Astruc, D., Gold Nanoparticles: Assembly, Supramolecular Chemistry, Quantum-Size-Related Properties, and Applications Toward Biology, Catalysis, and Nanotechnology, *Chem. Rev*. (Review) 2004, 104(1): 293–346.

Drexler, K., Nanosystems: Molecular Machinery, Manufacturing, and Computation, Wiley, 1992.

El-Sayed M. (Georgia Institute of Technology), Science Daily, Gold Nanoparticles May Simplify Cancer Detection: Available at: http://www.gatech.edu/news- room/release.php?id = 561, May 10, 2005.

Hill, D.M., Applications of Glyconanoparticles Biotechnology, Innovations in Pharmaceutical Technology, 2005 [Available at: http://www.inpharm.com/static/intelligence/pdf/MAG_365480.pdf].

Kukowska-Latallo, J.F., Candido, K.A., Cao, Z., Nigavekar, S.S., Majoros, I.J., Thomas, T.P., Balogh, L.P., and Baker, J.R., Nanoparticle Targeting of Anticancer Drug Improves Therapeutic Response in Animal Model of Human Epithelial Cancer, *Cancer Res*. 2005, 65(12): 5317–5324.

Loo, C. et al., Nanoshell-Enabled Photonics-Based Imaging and Therapy of Cancer, *Technol. Cancer Res. Treat*. February 2004, 3(1): 33–40.

Merkle, R., Self Replicating Systems and Molecular Manufacturing, J. *Brit. Inter. Soc*. 1992, 45: 407–413.

Owusu, Y.A., Chapman, H., Mundoma, C., and Williams, N., Novel Nanoparticles for Cancer Detection and Prevention, NSTI Nanotech Conference, Boston, MA, May 2006.

Owusu, Y.A., Advanced Manufacturing Processes and Materials, Textbook in Progress, 2005.

Owusu, Y.A. and Owusu, N.A., Fabrication of Nanorobot for Medical Applications in Asthma Treatment and Prevention, 32nd Southeastern Symposium on System Theory, FAMU-FSU College of Engineering, March 5–7, 2000, pp. 46–52.

Paciotti, G.F., et al., Colloidal Gold Nanoparticles: A Versatile Platform for Developing Tumor Targeted Cancer Therapies, Nano Science and Technology Institute, May 05, 2005.

Salata, O.V., Application of Nanoparticles in Biology and Medicine, J. *Nanobiotechnol*. 2004, 2: 3.

Svarovsky, S.A. and Barchi, J.J., Journal of American Chemistry, 2005.Author Queries

Environment Friendly Biodiesel from *Jatropha curcas*: Possibilities and Challenges

C. Baroi, E.K. Yanful, M.F. Rahman, and M.A. Bergougnou

Abstract Bio-diesel development from *Jatropha curcas* (JTC), a tropical plant, is currently being carried out in various parts of the world. High oil content of the JTC seed, high cetane number of the JTC biodiesel, its drought resistant characteristics, its toxicity, which makes it unwanted by both humans and animals, and its various other uses render this plant an extremely promising source for bio-fuel development in arid areas and rural communities in the developing world, in particular. Catalytic hydrocracking of various other vegetable oils, such as sunflower oil and soybean oil, has been reported. Chemical composition of JTC seed oil shows similarities in fatty acid composition to these oils. A two-stage catalytic hydrocracking process is proposed to convert JTC oil to high-cetane number biodiesel. If successful selectivities are obtained at the bench scale, this technology could be implemented in existing refineries in developing countries without major modification.

Keywords *Jatropha curcas* · biodiesel · catalytic hydrocracking

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1 Introduction

Environmental pollution and non-renewability of fossil fuels are some reasons why alternative fuels are gaining wide attention. Biodiesel is carbon-neutral, non-toxic and has a low emission profile compared to conventional petroleum (Meher et al. 2006). *Jatropha Curcas* (JTC) is a multipurpose plant with many attributes and considerable potential as an energy crop (Openshaw 2000). High viscosity and lower volatility are some of the problems with plant oils that have to be overcome before using them as fuel for conventional diesel engines (Meher et al. 2006). To date, transesterification is the most widely reported method of converting vegetable oils to biodiesel (Shah 2004). Some researchers have noted that catalytic hydrocracking of vegetables oils, such as soybean oil and sunflower oil, can produce successful synthetic diesel (Filho et al. 1992). Since JTC oil and the above mentioned oils have similar fatty acid compositions, it can be assumed that catalytic hydrocracking of JTC oil might produce high quality biodiesel. Researchers at the University of Western Ontario are planning to transform JTC oil to premium biodiesel using a two-stage catalytic hydrocracking process. This paper attempts to summarize the envisioned program. It also looks into the possibilities and challenges of JTC cultivation, the proposed technology and its application in the developing regions of the world.

2 *Jatropha curcas* – Origin and Description

JTC is a drought resistant tropical plant that belongs to the genus *Euphorbiaceae* (Gubitz et al. 1999). The JTC plant is a small tree or a large shrub that can reach a height of up to 5 m. The life- span of the JTC plant is more than 50 years (Henning 2000). This plant can be grown in low to high rainfall areas (Openshaw 2000) and is mainly used as living fence as it is toxic to both humans and animals (Gubitz et al. 1999). JTC has significant potential as an energy crop because its seed contains about 55% oil (Forson et al. 2004). With mechanical oil expellers, up to 75–80% of the oil can be extracted. With a hand press only 60–65% of the oil can be obtained (5 kg of the seeds give about 1 l oil) (Henning 2000). The properties of JTC oil are given below in Tables 1 and 2.

3 Possibility of Producing Biofuel from *Jatropha curcas*

Attempts have been made to produce biodiesel by transesterification of JTC oil and successful results were obtained. Conversion of JTC oil to useful fuels may also involve short contact time pyrolysis, catalytic cracking and catalytic hydrocracking. Table 2 shows that the calorific value of JTC oil is close to that of diesel oil and that the cetane value of JTC oil is slightly higher than that of diesel oil. The sulphur content of JTC oil is also much smaller than that of diesel oil in developing countries.

Table 1 Physico-chemical characteristics of Jatropha oil (JTC) (Akintayo 2004)

Parameter	JTC
Colour	Light yellow
Free fatty acid (mg/g)[a]	1.76 ± 0.10
Acid value (mg KOH/g)[a]	3.5 ± 0.1
Saponification value (mg KOH/g)[a]	198.85 ± 1.40
Iodine value (mg iodine/g)[a]	105.2 ± 0.7
Mean molecular mass	281.62
Unsaponifiable matter (%)	0.8 ± 0.1
Refractive index (25 °C)	1.468
Specific gravity (25 °C)	0.919
Hydroxyl value	2.15 ± 0.10
Acetyl value	2.16 ± 0.10
Viscosity (30 °C) cSt	17.1

[a]Values are mean ± standard deviation of triplicate determination.

Table 2 Comparison between Jatropha oil and diesel oil (adapted from Kandpal and Madan 1995)

Parameter	Diesel oil	Jatropha oil
Specific gravity	0.8410	0.9180
Sulphur (% wt)	1.2	0.13
Calorific value (cal/g)	10,170	9,470
Flash point (°C)	50	240
Cetane value	50	51

Table 3 shows that JTC oil contains mainly unsaturated and long chain (C_{18}) fatty acids. Linoleic acid is the dominant fatty acid in the oil. Soybean oil has a similar type of fatty acid composition and linoleic acid (60%) is also the dominant fatty acid in it (Filho et al. 1992). Sunflower oil and canola oil also contain unsaturated and long chain (C_{18}) fatty acids. Linoleic acid and oleic acid are the dominant fatty acids in sunflower oil and canola oil respectively. Sadrameli and Green (2007) reported that thermal cracking of canola oil in the temperature range 300–500 °C resulted in 38.1% to 14.8% of liquid products in which aromatics were 7.7–9.0%, whereas the gaseous product was 15–75% of the total product. Another study used $ZnCl_2$ catalyst to crack sunflower oil within the temperature range 610–690 K (Demirbas and Kara 2006). Soybean oil was thermally decomposed (pyrolysis) in the presence of N_2 and air using ASTM standard method D86-82 and the products contained nearly equal amounts of alkanes and alkenes and approximately 2% of aromatics. Soybean oil was also catalytically hydrocracked in the presence of NiMo/γAl_2O_3, giving 8.7% of gaseous products, 66.6% alkanes, 11.9% cycloalkanes, 4.3% alkylbenzenes (aromatics), 0.5% acids, 5.4% water and 2.4% losses (Filho et al. 1992). Several other vegetable oils were equally hydrocracked in the presence of NiMo/γAl_2O_3 catalyst and it was observed that the yield of gases in the converted material increased with the

Table 3 Fatty acid composition of *Jatropha curcas* (JTC) oil (Adapted from Adebowale and Adedire 2006; Filho et al. 1992; http://www.scientificpsychic.com/fitness/fattyacids1.html)

	Weight percentage		
Composition	Sunflower oil	Soybean oil	JTC oil
Palmitic acid (C16:0)	7.0	5.0	11.3
Stearic acid (C18:0)	5.0	1.6	17.0
Oleic acid (C18:1)	19.0	29.8	12.8
Linoleic acid (C18:2)	68.0	60.0	47.3
Arachidic acid (C20:0)	–	–	4.7
Arachidoleic acid (C20:1)	–	–	1.8
Behenic acid (C22:0)	–	–	0.6
C24:0	–	–	4.4

decrease in the fatty acid chain length and the degree of unsaturation of the vegetable oils (Filho et al. 1992). The degree of unsaturation in sunflower oil is greater than that of canola oil, which is why gaseous products are higher in canola oil. The oil composition is an important factor for the alkane content in the converted material. The higher the unsaturation, the higher is the formation of cycloalkanes and alkylbenzenes and the less will be the alkanes (Filho et al. 1992). Catalytic acidity and pore size affect the formation of aromatic and aliphatic hydrocarbons (Demirbas and Kara 2006). Unsaturated oil yields less gaseous products and hydrocarbons are produced by the reduction reaction of carboxyl groups rather than by decarboxylation of carboxyl group (Filho et al. 1992).

$$\text{Reduction: } C_{17}H_{35}COOH + 3H_2 \rightarrow C_{18}H_{38} + 2H_2O$$

$$\text{Decarboxylation: } C_{17}H_{35}COOH \rightarrow C_{17}H_{36} + CO_2$$

Decarboxylation can be either thermal or catalytic but reduction is only a catalytic process. In catalytic hydrocracking, a dual function catalyst is used. Its acid sites catalyze the cracking reaction while the metallic sites catalyze hydrogenation. Thus, when large unsaturated molecules are cracked into small molecules at the same time they are converted to saturated small molecules by hydrogenation. In catalytic hydrocracking, higher temperature favors chain cleavage but the formation of alkylbenzene probably originating from cycloalkanes is enhanced. Increase in hydrogen pressure favors the reduction of the carboxyl groups of fatty acids, with formation of water (Filho et al. 1992). The presence of carboxyl groups is undesirable, because they contain oxygen, which is corrosive to metals. When soybean oil was catalytically hydrocracked, the alkane content of the liquid product increased and the acid content was decreased substantially. On the basis of these results, it can be inferred that catalytic hydrocracking may yield better results for converting JTC oil into premium quality synthetic diesel with, hopefully, a higher cetane number.

4 Proposed Approach

The proposed plant would consist of two stages. The first stage would be a hydrotreating stage used for deep desulphurization, denitrogenation and possible deoxidation of raw JTC oil. The main products would be 'clean JTC oil', hydrogen sulfide, ammonia, water and smaller hydrocarbon fragments generated by a limited amount of JTC oil hydrocracking. The reactions are exothermic. Catalysts would use oxides of cobalt, nickel, vanadium and tungsten on alumina.

Hydrocracking would take place in the second stage on the 'clean JTC oil' coming out of the first stage distillation system. The catalyst would probably be a noble metal on a molecular sieve base. Sulfur and nitrogen are strong poisons for such a catalyst. The latter would be highly selective for compounds giving a high cetane number for JTC bio-diesel and would also minimize consumption of expensive hydrogen.

Figure 1 shows a simplified flow-plan for the first stage (hydrogenation). Raw JTC, fresh hydrogen and recycle hydrogen would be preheated against hot reactor products in a heat exchanger train and brought up to reactor temperature in a furnace. The hot combined liquid and gas phases would trickle down through one or several beds of catalyst particles of a size in the millimeter range. Cold quenching recycle hydrogen coming out of the high-pressure separator would cool the reactor. The hot reactor product would finally be cooled in the cooling heat exchanger train and in the water cooler train and go to a high-pressure separator. The gas phase would give the hydrogen recycle. The liquid phase would be depressurized in the low-pressure separator and go to the distillation train. The second stage (hydrocracking stage) would be similar to the first stage, and would have the clean JTC oil as the feedstock.

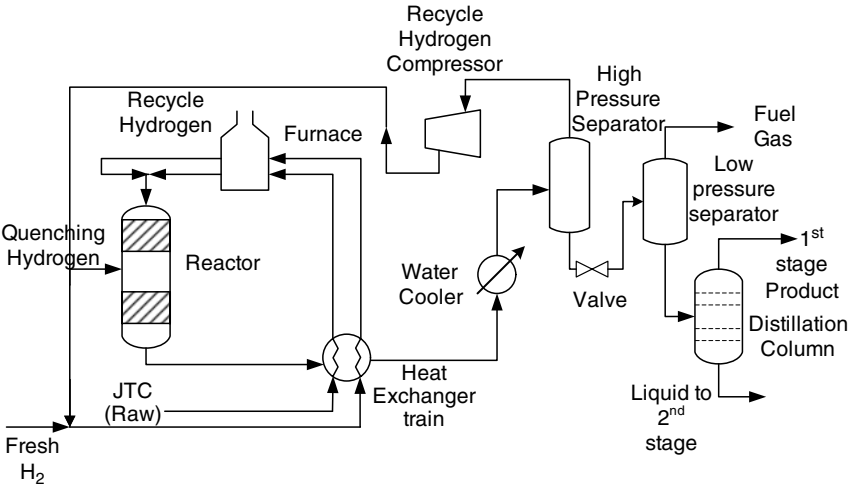

Fig. 1 Simplified flow-plan of the first stage for the proposed hydrocracking of JTC oil

Depending on the required bio-diesel specifications and with appropriate catalysts, only the first stage might be needed.

5 Challenges, Possibilities and Conclusion

The proposed program would start at the bench scale to test various hydrogenation and hydrocracking catalysts. Temperatures would be in the range 300–500 °C and pressure would be around 10 MPa (100 atm). Hydrogen diffuses through metals giving possibly explosive mixtures in air. Therefore, the laboratory should be well ventilated and have explosion proof electrical equipment. Material balances should be high. The life of a catalyst should be in the order of 1 year. Many of the refineries in the developing countries already have hydrocracking units installed in their refineries. If successful results are obtained at the laboratory scale, the process could be implemented in those countries without major modification of the existing refineries and could be operated by local manpower. However, the cost of the equipment, catalysts and analytical devices could be significant. In existing hydrogenation units (one stage) or hydrocracking units, co-processing of JTC oil with petroleum cuts might be cheapest.

Biomass supplies the bulk of the total energy demand in many of the world's poor nations (Ackom and Ertel 2005). Approximately 60% of the total energy consumption in Africa in 1995 came from biomass and it is estimated that, by 2030, approximately 823 million people will be relying on biomass in Africa (Ackom and Ertel 2005). This over-reliance on biomass could lead to serious environmental degradation and desertification in the developing world. Promotion of the multipurpose JTC would help remote rural communities address their energy needs and minimize environmental degradation. In many African communities JTC seeds are harvested by women and used for making soap, candle and medications. By selling these products, women in those rural areas could generate extra-income, which inherently would promote women empowerment and, also, high-value added unique compounds could be extracted from hydrogenated or hydrocracked JTC oil.

One important aspect of JTC diesel production is that it would not compete with food production, as JTC is toxic to both humans and animals and also because JTC plant can grow in dry wastelands with minimum input. The set up of JTC oil converting industries would create employment opportunities, provide a source of income for farmers and suppliers of feedstock and would, eventually, be a great source of revenue for governments. Also, it will reduce the dependency on fossil fuels and minimize crude petroleum import costs. Currently JTC cultivation is being promoted in a number of countries, including India, Ghana, Mali, Malawai, Zimbabwe, Egypt and Burkina Faso (Ackom and Ertel 2005), and some of those countries are good candidates for large scale industrial production of JTC biodiesel and other products. Comparatively cheaper JTC biodiesel would encourage farmers to use biodiesel for irrigation purposes and also could be used by the transportation sector and industry. Government and donor agencies would have to come up with necessary planning and appropriate financial support to subsidize establishment costs for industry to develop JTC biodiesel resource. This

would eventually stimulate economic empowerment through employment and poverty reduction (Ackom and Ertel 2005), and promote sustainable and appropriate development in the developing and drought prone regions of the world.

References

Ackom, E.K.; Ertel, J., 2005. An alternative energy approach to combating desertification and promotion of sustainable development in drought regions. Forum der Forschung, 18, 74–78.

Adebowale, K.O.; Adedire, C.O., 2006. Chemical composition and insecticidal properties of the underutilized *Jatropha curcas* seed oil. African Journal of Biotechnology, 5(10), 901–906.

Akintayo, E.T., 2004.Characteristics and composition of *Parkia biglobbossa* and *Jatropha curcas* oils and cakes. Bioresource Technology, 92, 307–310.

Demirbas, A.; Kara, H., 2006. New options for conversion of vegetable oils to alternative fuels. Energy Sources, Part A, 28, 626–629.

Filho, G.; Rocha, N.; Brodzki, D.; Djega-Mariadassou, G., 1992. Formation of alkanes, alkylcycloalkanes and alkylbenzenes during the catalytic hydrocracking of vegetable oils. Fuel, 72(4), 543–549.

Forson, F.K.; Oduro, E.K.; Donkoh, E.H., 2004. Performance of Jatropha oil blends in a diesel engine. Renewable Energy, 29, 1135–1145.

Gubitz, G.M.; Mittelbach, M.; Tranbi, M., 1999. Exploitation of the tropical oil seed plant *Jatropha curcas* L. Bioresource Technology, 67, 73–82.

Henning, R., 2000. The Jatropha booklet – a guide to the Jatropha system and its dissemination. GTZ-ASIP-Support-Project Southern Province, Choma. http://www.jatropha.de/documents/jcl-booklet-o-b.pdf. Visited: 1600 hours, 21 June, 2006.

Kandpal, J.B.; Madan, M., 1995. Jatropha curcus: A renewable source of energy for meeting future energy needs. Renewable Energy, 6(2), 159–160.

Meher, L.C.; Vidya, S.D.; Naik, S.N., 2006. Technical aspects of biodiesel production by transesterification – a review. Renewable and Sustainable Energy Reviews, 10, 248–268.

Openshaw, K., 2000. A review of Jatropha curcas: An oil plant of unfulfilled promise. Biomass and Bioenergy, 19, 1–15.

Sadrameli, S.M.; Green, A.E.S., 2007.Systematics of renewable olefins from thermal cracking of canola oil. Journal of Analytical and Applied Pyrolysis, 78(2), 445–451.

Shah, S., 2004. Biodiesel preparation by lipase-catalysed transesterification of Jatropha oil. Energy & Fuels, 18, 154–159. http://www.scientificpsychic.com/fitness/fattyacids1.html. Visited: 1244 hours, 20 June, 2007.

Thermal Utilization of Solid Recovered Fuels in Pulverized Coal Power Plants and Industrial Furnaces as Part of an Integrated Waste Management Concept

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Abstract Solid Recovered Fuels (SRF) are highly heterogeneous mixtures generated from high calorific fractions of non-hazardous waste materials intended to be fired in existing coal power plants and industrial furnaces (CEN/TC 343 2003). They are composed of a variety of materials of which some although recyclable in theory, may have become in forms that made their recycling an unsound option. Their use is regulated under EU regulations and requires specification for commercial and regulatory purposes. The use of waste as a source of energy in itself is an integral part of waste management, as such within the framework of the European Community's policy-objectives related to renewable energy, an approach to the effective use of wastes as fuel sources and energy recovery from wastes is outlined in documents such as the European Waste Strategy.

This work involves a characterization step for SRF especially for co-firing in pulverized coal power plants for the purpose of generating heat and electricity. The nature of SRF requires a thorough understanding of their combustion properties before optimal energy recovery can be realized. The characterization process involves among other things lab-scale experiments that critically examine the fuel concerning their physical and chemical properties. The de-volatilization, ignition and combustion processes associated with different types of SRF are also studied using a thermo-gravimetric analyzer (TGA). Based on these experiments, suggestions are made for a successful application of SRF in power plants and industrial furnaces. Finally, an overview of the potentials of waste materials as fuel and a source of energy is discussed.

Keywords Solid recovered fuels (SRF) · municipal solid waste (MSW) · integrated waste management concept · co-combustion/co-firing · thermo-gravimetric analysis

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1 Introduction

The production and thermal utilization (energy recovery) of Solid Recovered Fuels (SRF) from bio-waste, residues, mixed- and mono waste streams is fast becoming a key element in an integrated waste management concept, as the deposition of untreated waste stream in landfills is not an option in the future as outlined in the European Landfill directive (1999/31/EC). The key elements of such waste management concept would be recycling/reuses, mechanical- and biological processes (M/B), solid recovered fuel production and municipal/hazardous waste incineration (MSWI). The targeted hierarchy (Fig. 1) within this concept would be material recovery, energy recovery and final disposal according to the directive (1999/31/EC).

The implementation of solid recovered fuel production in an integrated waste management concept demands a potential market for the products, which can be found in the energy sector, and in product-oriented sectors such as cement or lime industries by substituting fossil fuels. Figure 2 illustrate the process scheme for SRF utilisation in industrial processes and power plants (Gawlik and Ciceri 2005).

By definition, Solid Recovered Fuels are highly heterogeneous mixtures generated from high calorific fractions of non-hazardous waste materials intended to be

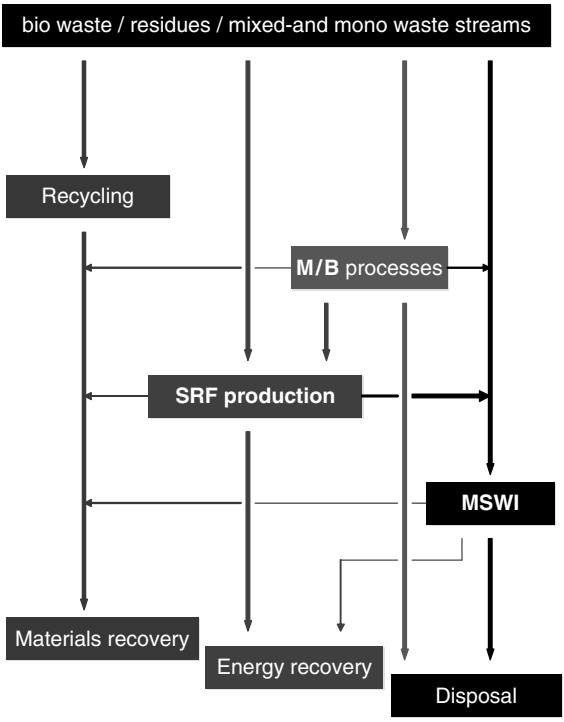

Fig. 1 The targeted hierarchy within the waste management concept

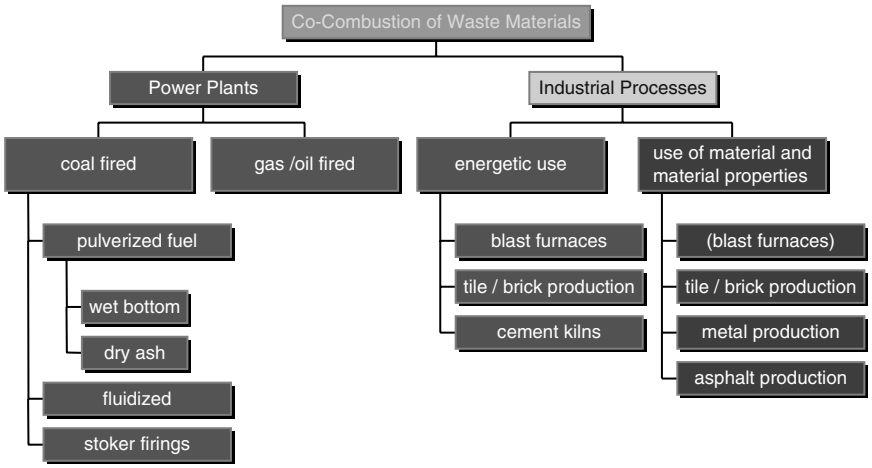

Fig. 2 Process scheme for SRF utilisation

fired in existing coal power plants and industrial furnaces (CEN/TC 343 2003). They are composed of a variety of materials of which some although recyclable in theory, may have become in forms that made their recycling an unsound option. Their use is regulated under EU regulations and requires specification for commercial and regulatory purposes. Figures 3a, b below shows a type of SRF called *Substitutbrennstoff aus Siedlungsabfaellen* (SBS®) –high calorific fraction generated from municipal solid waste (MSW)– and its percentage composition (Dunnu et al. 2006).

Co-combustion of SRF such as SBS® in existing coal fired utilities can have a huge impact on a power plant performance. Due to different physical and chemical properties of these fuels in comparison with coal, a number of processes including milling, feeding, combustion, heat transfer, and steam production can be affected. With the current knowledge of co-combustion, it is not possible to predict the impact of a single SRF or their mixtures on a power plant performance. With the knowledge of the physical, chemical and biogenic characteristics of the SRF, some of the negative impacts of co-combustion on the performance of power plants can be avoided and subsequently, carrying out expensive large-scale tests and trials in order to determine the suitability of a solid recovered fuel at certain plants can be minimized. Characterization of SRF is therefore essential for the purpose of quality assurance and quality management system for the smooth operation of plants and other industrial furnaces.

2 Waste-to-Energy a Better Option

Waste disposal and the availability of cleaner energy sources are two major issues facing Europe and the rest of the world. Both landfills and the emission of greenhouse gases present serious health and environmental threats. Finding solutions to

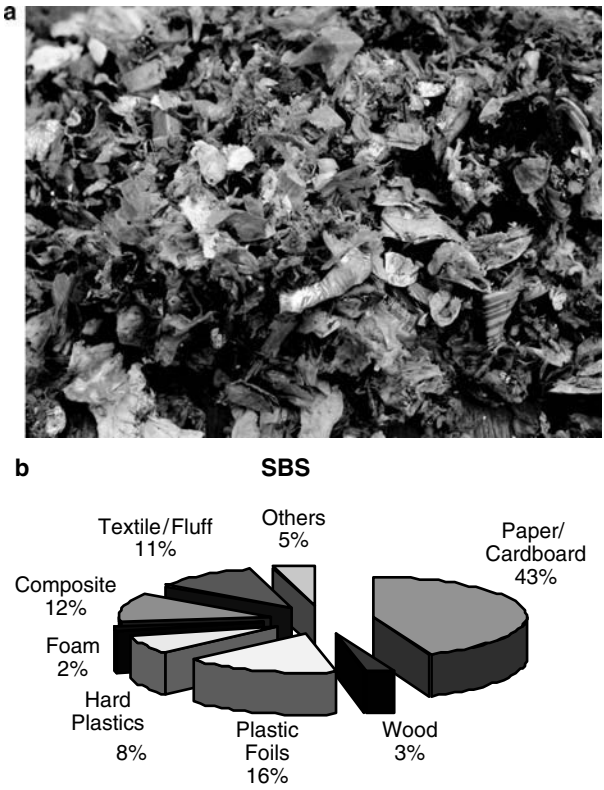

Fig. 3 (a) Solid recovered fuel (SBS®); (b) Composition of SBS®

these threats therefore advance waste-to-energy (WTE) concept as a potential option that should not be overlooked. The production of SRF from non-hazardous bio-waste, residues and other mixed- and mono waste streams represents a potential solution to both cleaner burning fuels compared to fossil fuels and waste materials that are currently disposed of in landfills.

2.1 Environmental Benefits

Using waste as an energy source would reduce the amount of fossil fuels used. Under normal conditions, 1 t of waste can generate 3.5 MW of energy, as much energy as contained in 300 kg of fuel oil (Fitze 2002). If this kind of energy is recognized as partially renewable resources, then fossil fuels can to some extent

be substituted. The environmental benefits would be enormous if municipal solid wastes (MSW) now going to landfills are turned into SRF and subsequently combusted in thermally efficient Waste-to energy facilities. Approximately 1.4 billion tonnes of MSW worldwide are disposed in landfills, deep enough to generate biogas of approximately 50% methane and 50% CO_2. The annual generation of methane is estimated at 62 million tonnes, of which less than 10% is recovered in controlled landfill equipped to capture biogas (Themelis 2006). As a matter of fact, methane is 20 times more potent as a greenhouse gas than carbon dioxide (Veltzé 2005). As a result, if the contribution of landfill non-captured methane to greenhouse gas emission is considered, it will be clear that a gradual move from landfill to WTE is one of the low-hanging fruits in reducing global emission of greenhouse gases.

Figure 4 shows the projected situation of the German waste market 2006 with an expected capacity deficit of approximately 4.5 Mt. Co-firing SRF in energy production throughout Europe, even in small thermal shares, offers enormous potential as a sustainable, efficient and environmentally friendly waste-to-energy technology. The specific CO_2 emission based on initial SRF quality (BGS® quality 2, LHV 13.5MJ, 0.4 wt% Cl_{th}) with a biogenic fraction of 50 wt% is 0.04 kg CO_2/MJ, compared to 0.12 kg CO_2/MJ for brown coal (Kronberger 2001).

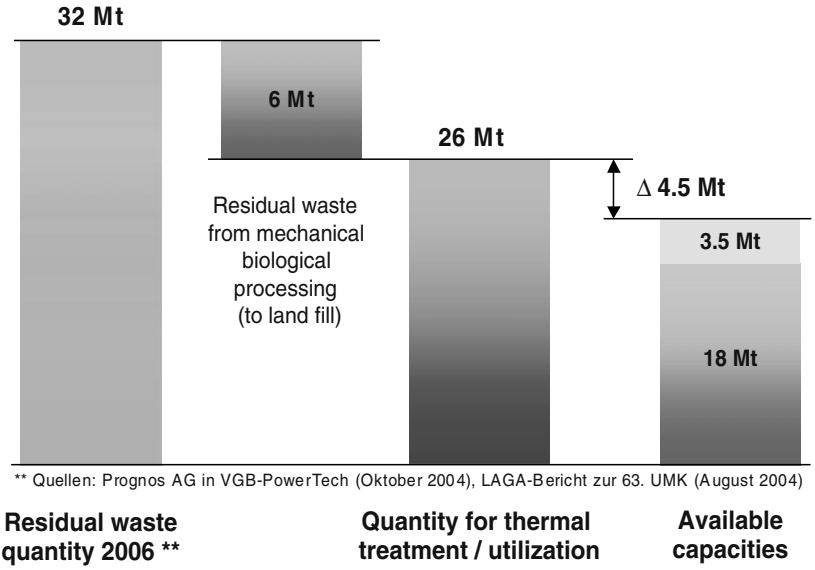

Fig. 4 Projected situation ion of Germany waste market 2006 (PROGNOS 2004)

3 Experiments

3.1 Fuel Analysis

Particle size and reactive surface area of fuel have the largest influence on a combustion process, as all matter and energy transport take place (Kock 2002). Both renewable and fossil fuels consist of a combustible organic fraction and an inert inorganic part (mineral matter). The main elements in most solid fuels are carbon (C), hydrogen (H), oxygen (O), sulphur (S) and nitrogen (N). Besides, there exist minor constituents like chlorine (Cl), potassium (K), and sodium (Na). The share of these elements in solid fuels varies, influencing the pyrolysis and combustion characteristics. Particularly the share and nature of the inorganic compounds and trace metals affect the fuel reactivity (Jenkins et al. 1998). Fuels suitable for co-firing with coal include not only typical biomass fuels like wood and straw, but also waste streams from agriculture, industrial and municipal sources.

The characterization of SRF involves the vdetermination of the physical/mechanical, chemical and biological components of a given fuel. While it is important to determine the biogenic characteristics of SRF because it enable the calculation of the CO_2 emission savings, this work is limited only to characterizing SRF based on their physical/mechanical properties, and major chemical elements.

The SRF used for the characterization were milled down to particle size 1 mm with a rotor-sieve cutter. Because of the heterogeneous nature of this type of fuel, a representative sample can easily be achieved with a finer particle size distribution and furthermore minimise the heat and mass transport resistances in the boundary layer and within the particles. The proximate and ultimate analyses of different fuels were conducted. The fuels included SBS, shredded rubber tyre, paper/plastic mixture, and demolition wood. In addition, base line analyses of lignite and hard coal as referenced fuels were also included.

3.2 Thermo-Gravimetric Investigation

The behaviour and release of volatile components of SRF and the referenced fuels were investigated by thermo-gravimetric analysis (TGA). With the standardised methods according to DIN51718-DIN51720, the mass fractions of water, volatiles, fixed-carbon and ash were determined. For the combustion behaviour the temperature range in which the volatiles are released are of interest. The TGA analyzer was charged with SRF test portions each of about 1 ± 0.1 g. With a heating rate of 5 °C/min, the test portions were heated up to a temperature of 900 °C under a reducing atmosphere (N_2). At 106 °C the temperature was kept constant to evaporate the moisture content of the fuel, the heating continues when the mass deviation of the samples was less than 0.1%. The weight loss curve of the heat-up ramp from 106 °C to 900 °C with Nitrogen atmosphere gives information about the release of the volatile matter which is composed mainly of hydrocarbon groups.

4 Results

The results from the proximate and ultimate analysis presented in Table 1 shows that demolition wood has the largest percent of volatile matter followed by SBS, shredded tyre, lignite, and hard coal in the respective order. The de-volatilization behaviour of the respective fuels investigated with a thermo-gravimetric analyzer is also presented in Figure 5.

Table 1 Fuel analysis

	SBS	Wood	Shredded tyre	Lignite (DE)	Hard coal (SA)
Proximate analysis, % (as received)					
Moisture, 106°C, %	1.7	5.7	0.62	10.2	3.6
Volatile matter, %	77.8	77.9	52.8	48.6	21.6
Fixed carbon, %	13.1	0.022	22.7	36.6	56.2
Ash, 550°C (SRF); 815°C (coal), %	7.3	16.1	23.8	4.6	18.6
Ultimate analysis, % (as received)					
C, %	52.7	48.2	83.3*	57.5	65.3
H, %	8.1	6.5	6.9*	5	3.9
N, %	0.6	<0.3	<0.3*	0.52	3.5
S, %	<0.3	<0.3	2.7*	<0.3	1.3
Cl, % LHV, J/g	25,053	18,780	29,095	22,350	24,931

*Without metal constituent.

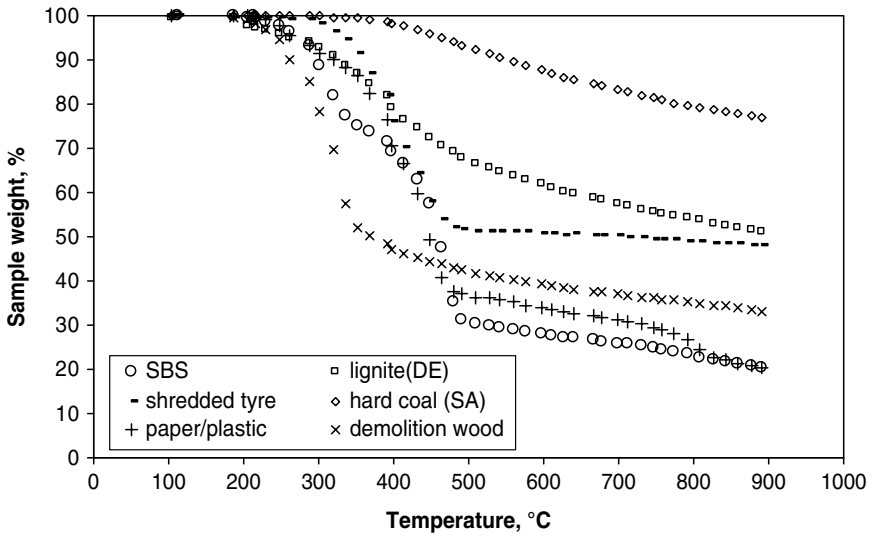

Fig. 5 TGA curves of different SRF and coal comparing weight loss due to devolatilization

The TGA curves shows that the temperature at the onset of primary de-volatilization for all the SRF is around 220 °C and ends at about 490 °C. Large percentage of the volatile matter is released at much lower temperature as compared to the primary fuels, lignite and hard coal, and it occurs within a narrow temperature range. Demolition wood exhibited maximum primary weight loss at 350 °C whereas that of paper/plastic, SBS, and shredded tyre occurred at 490 °C. Volatiles released at low temperatures favours particle ignition and improve stable flame conditions, therefore the release of large amounts of combustible matter at low temperatures show that a good ignition can be expected for all the SRF tested.

5 Conclusion

- The concept of using waste as a source of fuel to be co-fired as part of an integrated waste management concept with the aim of energy recovery and not disposal is an effective way to reduce the amount of landfill un-captured methane emission which is more potent a greenhouse gas than CO_2 (combustion product).
- The biogenic fraction of SRF makes it partially renewable and partially CO_2 neutral.
- The thermo-gravimetric analysis performed on the SRF is an essential tool to determine the suitability of fuel to be co-fired in power plants or industrial furnaces, however, it is not a blue print since other factors such as slagging, fouling, sintering, and corrosion potential also contribute significantly as to whether a particular SRF can successfully be used. Not withstanding this, the TGA provided very useful information concerning the de-volatilization of the SRF. All the waste fuels investigated showed an early de-volatilization and this occurs at relatively low temperatures. This phenomenon substantially predicts a good ignition if such SRF are to be co-fired with coal in power plants and industrial furnaces.

In sum, it should be clearly stated that the number one objective remains the removal of waste in an environmentally correct manner, without forgetting that energy recovery can take the place of other fossil energies, and in doing so reduce the impact of vhuman activity on the environment.

References

Draft business plan of CEN/TC 343, 2003, Solid Recovered Fuels.

Dunnu G., Hilber T., and Schnell U., 2006, Advanced size measurements and aerodynamic classification of solid recovered fuel particles. Energy & Fuels, 20(4): 1685–1690.

Fitze U., 2002, Les ordures – source d'énergie. UMWELT Review, no. 3/02.

Gawlik B. M. and Ciceri G., 2005, QUOVADIS waste-to-fuel conversion, DG JRC Workshop, Ispra, ISBN92-894986110.

Jenkins B. M., Baxter L. L., Miles Jr. T. R., and Miles T. R., 1998, Combustion properties of biomass. Fuel Processing Technology, 54: 17–46.

Kock O., 2002, Regenerative Brennstoffe – Charakterisierung des Brennverhaltens. 7. Fachtagung Thermische Abfallbehandlung, Band 20, Technische Universität Dresden, pp. 195–209.

Kronberger R., 2001, Waste to recovered fuel – cost-benefit analysis, GUA Gesellschaft für umfassende Analysen GmbH, Wien.

Prognos AG in VGB-PowerTech (Oct. 2004); LAGA Bericht zum 63. UMK (Aug. 2004).

Themelis N., 2006, Better together: gas turbine cogeneration improves energy recovery from WTE plants. Waste Management World, July–August: 97–105.

Veltzé S. A., 2005, Editorial, proper management of methane at landfills is key to alleviating the greenhouse gas problem. Waste Management World, March/April: 6 of 96.

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