UNIVERSITÀ DEGLI STUDI DI BRESCIA

CeTAmbLAB

Research laboratory on Appropriate Technologies for Environmental Management in resource-limited Countries

Il progetto è co-finanziato dall'Unione Europea

Sustainable Livelihoods

REDUCING HEALTH RISKS AND ENVIRONMENTAL ISSUES USING SOLID WASTE BEST PRACTICE AND IMPROVED COOKSTOVES AMONG RURAL COMMUNITIES IN GHANA

Giovanni Vinti, Mentore Vaccari, Terry Tudor

February 2020

CeTAmb LAB

Laboratory Centre on Appropriate Technologies

for Environmental Management in Resource-limited Countries

Director: Prof. Sabrina Sorlini

Department of Civil, Environmental, Architectural Engineering and Mathematics (DICATAM)

University of Brescia, via Branze 43, 25123, Brescia (Italy)

ISBN 978-88-97307-17-4

Cover photo: © G. Vinti, 2019

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of CeTAmb LAB (University of Brescia) and do not necessarily reflect the views of the European Union.

Reducing **health risks and environmental issues** using solid waste best practice and improved cookstoves among rural communities in Ghana

Giovanni Vinti[1], Mentore Vaccari[1], Terry Tudor[2]

[1] Laboratory Centre on Appropriate Technologies for Environmental Management in Resource-limited Countries (CeTAmb LAB), University of Brescia, via Branze 43, Brescia (Italy)

[2] SusConnect Ltd. The Royal Ordnance Depot, Building 86, Unit 4, Weedon Bec. Northamptonshire. UK. NN7 4PS

Contents

Preface

The following document was developed in the context of the project "*Sustainable Livelihoods: Linking sustainable agriculture and organic waste management to social protection and decent work for unemployed youth, smallholder and women farmers in the savannah ecological zones of Brong Ahafo and Northern regions*". The project is co-funded by the European Union in Ghana in the framework of the CSO RISE programme - Civil Society Organizations in Research and Innovation for Sustainable Development. It is being implemented by the Italian NGO CISS, in partnership with the Ghanaian NGOs NECPAD and RUDEYA, and the CeTAmb LAB (University of Brescia, Italy).[1]

This document represents a scientific and technical contribution of the approaches being utilised to implement best practice for the effective management of solid waste and energy, and to reduce health and environmental risks among the Ghanaian communities involved in the project. It can be seen as an addition to traditional WASH (water, sanitation and hygiene) campaigns.

The first part of the document is mainly aimed at technical experts conducting training activities in rural Ghanaian communities or similar geographical regions. It outlines an overarching empirical context for the choice of the 'appropriate' technologies being utilised in the project (improved cookstoves, composting bins and anaerobic digesters). In this way, the trainers would be able to better understand, contextualize, interpret and explain the necessary decision-making processes, to a range of technical and non-technical audiences.

The last part of the document (the Annex) contains a series of best practice concepts, to help communities in rural contexts reduce the health and environmental risks faced.

This document represents a contribution to assist rural communities in Ghana and similar regions, to reduce the health and environmental risks posed.

The authors

[1] For more information about the project visit: http://www.cissong.org/sostenibilita-ambientale-e-supporto-allimpresa-il-ciss-a-sostegno-del-ghana/

Introduction

A key underlying element in the Sustainable Livelihoods project is the concept of sustainable development. The concept was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). With this context, the United Nations (2015) aimed to achieve this “outcome” through the 17 Sustainable Development Goals (SDGs) shown in Figure 1.

Figure 1 – The 17 SDGs included in the 2030 Agenda for Sustainable Development

Given the focus of the Sustainable Livelihoods project, a number of these SDGs have been taken into consideration, in particular good health and well-being (SDG 3), gender equality (SDG 5), clean water and sanitation (SDG 6), responsible consumption and production (SDG 12), climate action (SDG 13), and life on land (SDG 15).

Considering SDG 3, ‘good health and well-being’, the United Nations state that air pollution (both outdoor and indoor), increases the risk of cardiovascular and respiratory disease, leading in 2016 to about 7 million deaths worldwide. Sub-Saharan Africa has among the highest mortality associated with air pollution, as a large proportion of the population still relies on polluting fuels and technologies for cooking. Furthermore, inadequate and unsafe drinking water, sanitation and hygiene are linked to 60 per cent of the disease burden from diarrhoea.

SDG 5, ‘gender equality’, aims to empower all women and girls, ensure women’s full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life (target 5.5).

SDG 6 focuses on ‘clean water and sanitation’. Indeed billions of people still lack safe water, sanitation and hygienic facilities. Among the related targets, 6.3 aims by 2030, to improve water quality by reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials.

SDG 12, ‘responsible consumption and production’, starts from the assumption that urgent action is needed to ensure that current material needs do not lead to the over-extraction of resources or to the degradation of environmental resources. In this context, policies that improve resource efficiency, reduce waste and facilitate the widespread uptake of sustainable practices are crucial. Among the related targets, 12.5 aims by 2030, to substantially reduce waste generation through prevention, reduction, recycling and reuse.

SDG 13, 'climate action', highlights how climate change is occurring at rates that are much faster than previously anticipated and its effects are being felt worldwide. Among the related targets, 13.3 emphasizes the need for improved education, awareness-raising and human and institutional capacity building to enable climate change mitigation and adaptation. Furthermore, target 13.B aims to promote mechanisms to facilitate capacity building for effective climate change-related planning and management in least developed countries, including focusing on women, youth, and localized and marginalized communities.

Finally, SDG 15, 'life on land', aims to protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss.

The difficulties that the rural communities involved in this project face are well represented by the aforementioned SDGs. However, in this document, attention is given to issues related to energy use, solid waste management and the related environmental and health issues. As a consequence, the main objective is to explain how best to effectively manage these challenges. The consequent approach consists primarily of minimizing the use of natural resources by utilizing the concept of a circular economy, as well as reducing polluting and dangerous contaminant emissions.

In the following chapters, first health risks and environmental issues related to rural cookstoves and solid waste mismanagement among rural communities are introduced. Suggested approaches in the form of using improved cookstoves, composting bins and anaerobic digesters at household level are then described.

Finally, the Annex illustrates a series of best practice techniques to reduce health and environmental risks in rural communities.

Health risks related to rural stoves

Household air pollution (HAP) generated from cooking and heating with biomass stoves is associated with over 1.6 million premature deaths every year, mainly in low- and middle-income countries (Liao et al., 2019). Indeed, to fulfil their cooking needs many people in poor areas use three-stone fires or other inefficient traditional stoves (Parmigiani et al., 2014). These practices are very common in rural areas of Ghana, as it has been witnessed during field missions related to the Sustainable Livelihoods project. Monitoring conducted by Cetamb LAB staff among many communities between November and December 2019 highlighted high level of $PM_{2.5}$ and PM_{10} (i.e. particulate matter with a diameter of less than 2.5 and 10 micrometres, respectively). In particular, PM concentration near to indoor kitchens, as well as in internal courtyards was often higher than 100 $\mu g/m^3$ during cooking time. In some cases, concentrations were even higher than 1,000 $\mu g/m^3$. It should be borne in mind that the limits suggested by the World Health Organization (WHO), for both indoors and outdoors are between 10 $\mu g/m^3$ (annual mean) and 25 $\mu g/m^3$ (24-hour mean) for $PM_{2.5}$, and between 20 $\mu g/m^3$ (annual mean) and 50 $\mu g/m^3$ (24-hour mean) for PM_{10} (WHO 2010; 2014).

According to WHO (2014), in low-income regions, indoor exposure to pollutants from combustion related to household open fires or traditional stoves, increases the risk of acute lower respiratory infections and associated mortality among young children. Furthermore, among adults it is also a major risk factor for cardiovascular disease, chronic obstructive pulmonary disease and lung cancer (WHO, 2014).

With this in mind, recently, Clasen and Smith (2019) argued it is necessary to combine the traditional WASH with HAP, in order to improve the effectiveness and efficiency of interventions to reduce the significant disease burden associated with both.

In addition, rising use of firewood, related to inefficient traditional stoves and three-stone fires, plays a crucial part in the increase in deforestation and the amount of time spent (predominantly by women and children), searching for firewood. The demand for local biomass energy can often exceed the natural re-growth of local resources (Urmee and Gyamfi, 2014).

Health risks related to the mismanagement of municipal solid waste

The ineffective management of municipal solid waste (MSW) can lead to environmental contamination and health risks. The most dangerous practices, such as open dumping and uncontrolled burning, are mainly common in low- and middle-income countries (Cointreau, 2006; Ferronato and Torretta, 2019). Furthermore, the poor quality of road connections makes the management of the waste in many rural villages even more difficult.

Dumpsites are areas in which MSW is disposed of without any control or environmental protection. As a consequence, they can pose several public and environmental health risks, including groundwater pollution, heavy metals contamination in the soil, and greenhouse gas emissions (Vaccari et al., 2018). In Ghana, the organic fraction represents more than 60% of MSW (Miezah et al., 2015), with even higher rates among rural communities, as has been observed during project field missions. Other waste fractions (e.g. plastics, and some glass, paper and metal), are generated in lower quantities.

Open burning of waste, sometimes in dumpsites themselves, poses significant risks. For example, the practice generates high level of $PM_{2.5}$, PM_{10} and other dangerous substances that if inhaled may cause respiratory problems. These issues were witnessed during the field mission held in November 2019, where $PM_{2.5}$ and PM_{10} concentrations were many times above the limits suggested by WHO (2014). Open burning, particularly of plastics, can also generate carcinogenic and toxic contaminants, such as dioxins and furans (Fiani et al., 2013). Although these contaminants can be absorbed by inhalation, their main route of exposure is through ingestion of contaminated foods of animal origin and their derivatives (WHO, 2019). Among rural communities involved in the Sustainable Livelihoods project, subsistence agriculture is common. Thus the risk of dioxin bioaccumulation through food chain is very high. The field missions highlighted that most dumpsites as well as open burning activities were located within inhabited centres, posing a higher level of risks (see Figure 2).

Figure 2 – Farm animals in a dumpsite located within a Ghanaian village (© G. Vinti, 2019)

As a consequence, when it is not possible to change these bad practices in a short time, at least waste dumping and/or open burning should be carried out far from inhabited centres.

Furthermore, during the field missions it was noted that some farmers collected waste from dumpsites, using it as compost on their land. Such practices have a high risk potential both for the environment and human health. Consideration should therefore be given to separating out the organic fraction of the MSW at source, thus avoiding different fractions of waste being mixed.

Managing MSW through open dumping and landfilling is a potentially important source of greenhouse gas (GHG) emissions, especially methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) (Ngwabie et al., 2019). For example, emissions from waste disposal represented some 8.1% of the total GHG emissions in Africa (Couth et al., 2011). This emission rate has most likely increased due to rising populations and increasing urbanization. In this context, the organic fraction of MSW, which is composed of mainly food waste such as fruits and vegetables, plays a key role. Indeed, it decomposes in landfills and dumpsites to produce the aforementioned gases. The majority of these emissions are from the anaerobic biodegradation of the waste in landfills and dumpsites. Dumpsites pose a higher risk because the gases generated are not collected. Methane has a greenhouse potential about 20 times higher than CO_2. Thus converting CH_4 to CO_2 through complete combustion (e.g. with anaerobic digesters) is another way to mitigate the emissions (Vögeli et al., 2014).

Improved cookstoves

To overcome the aforementioned issues related to three-stone fires and inefficient traditional cookstoves, a solution was found through the use of improved cookstoves. The main advantages are reduced respiratory risks due to the use of a ventilation system (i.e. a chimney), a reduction in the need for fuel with the improvement of the kitchen layout, and thermal efficiency. Indeed, it has been demonstrated (e.g. see Jetter and Kariher, 2009) that compared to traditional cooking methods, improved cookstoves can enhance fuel efficiency and reduce pollutant emissions.

Rehfuess et al. (2014) also estimated that the impact of an intervention with improved biomass cookstoves using chimneys, compared with traditional (open-fire) stoves, can reduce $PM_{2.5}$ exposure among women from 270 $\mu g/m^3$ to 120 $\mu g/m^3$.

The newly designed cookstoves, also known as advanced biomass cookstoves, are based on improved design principles. They have enhanced combustion efficiency and thus, significantly reduced fuel consumption. Potentially, they also have the ability to get carbon credits because of their contribution to climate change mitigation. There are also co-benefits in terms of energy access for poor people, as well as improved health, environmental, agricultural and economic conditions. A schematic example of improved cookstove is shown in Figure 3.

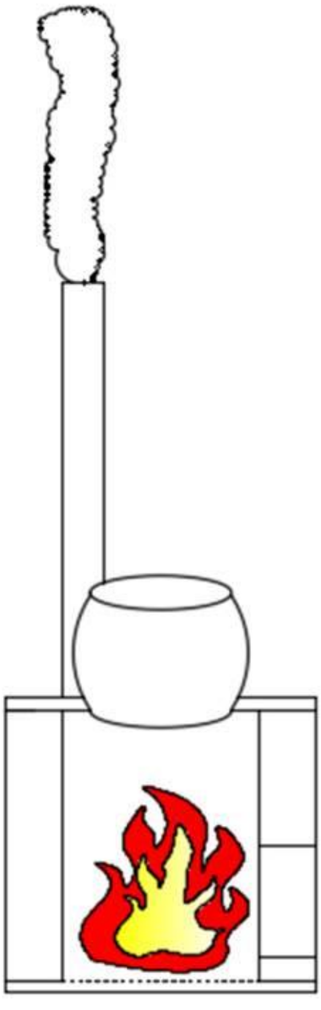


Figure 3 - Example of improved cookstove

Kumar et al. (2013) noted that to increase the combustion and heat transfer efficiencies of cookstoves, different components and prototypes have been developed and introduced over the years. The earlier improved cookstoves generally had chimneys and closed combustion chambers, but they easily cracked and degraded with repeated heating and cooling. As a consequence, a systematic investigation of the heat transfer and combustion efficiency of a stove design is often necessary in the laboratory, which in turn, may help to ensure that they have a significant improvement over the traditional stoves. New cookstoves should be based on well-defined standards that include safety, efficiency, emissions, durability and cost.

The use of a chimney is very important in improved cookstoves. For instance, a study in Sri Lanka found mean 48-h personal $PM_{2.5}$ concentration values of 76 and 201 $\mu g/m^3$ for women in households using cookstoves with and without a chimney, respectively (Chartier et al., 2017).

The use of improved cookstoves also reduces deforestation. Furthermore, families use less wood, charcoal or other fuels, and therefore spend less time and money on the related activities.

Solid waste management

As previously mentioned, the organic fraction of MSW (or biowaste) represents the majority of MSW produced at household level among the Ghanaian communities involved in the Sustainable Livelihoods project. As a consequence, focusing on this fraction would significantly reduce the amount of waste disposed of in dumpsites. Furthermore, this activity would enable recovery of value from the waste, using the concept of a circular economy. Indeed, biowaste can serve as recovery resource or energy source which may help rural communities to achieve sustainable development. The options taken into consideration in the project include the use of:

- Composting bins
- Floating-drum anaerobic digesters.

Composting bins

Home composting can represent an environmentally sustainable solution for managing MSW across rural areas. Good quality compost can in turn be used to increase agricultural productivity (Mihai and Ingrao, 2018). Composting is controlled decomposition, and the natural breakdown process of organic residues. It transforms raw organic waste materials into biologically stable, humic substances that make excellent soil amendments. Home composting is more practical, safe and economically viable if the biowaste is well segregated at source, and if critical parameters are properly managed (Van Fan et al., 2016).

With this in mind, the proposed solution consists of the use of composting bins at household level, using a design similar to that shown in Figure 4. They can be made of metal, plastic or natural materials such as wood.

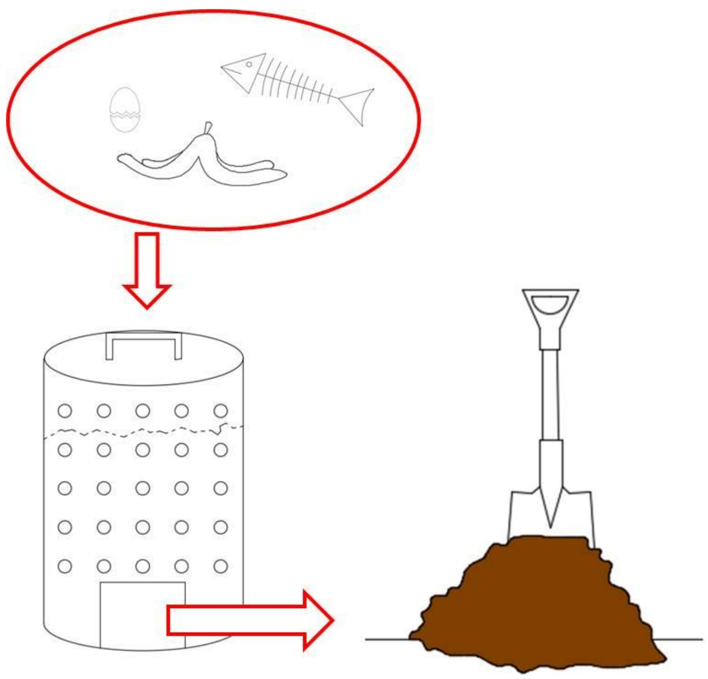


Figure 4 - Example of composting bin

Waste is added every day at the top of the bin, with compost removed from the bottom after about 30-60 days.

With a Ghanaian average production rate of MSW per capita of about 0.47 kg/(person×day), of which more than 60% is biowaste (Miezah et al., 2015), it is estimated that there would be an annual production rate per capita of biowaste of approximately 100 kg/(person×year). Taking account of reduction during the reaction processes, a family of five could obtain about 200-300 kg of compost per year.

Floating-drum anaerobic digesters

Anaerobic digestion (AD) is a microbiological process whereby organic matter is decomposed in the absence of oxygen. Using an engineered approach and controlled design, the AD process is applied to process organic biodegradable matter in airproof reactor tanks, commonly named digesters, to produce biogas (Vögeli et al., 2014). This technology has already been successfully implemented at household level in some low- and middle-income settlements, such as Dar es Salaam (Tanzania) or Gobernador Crespo (Argentina) (Vögeli et al., 2014).

In the project, only the organic fraction of the MSW (i.e. no faecal matter), will be utilized. In this way, there will be greater public acceptance and lower health risks. A floating-drum digester will be employed as shown in Figure 5.

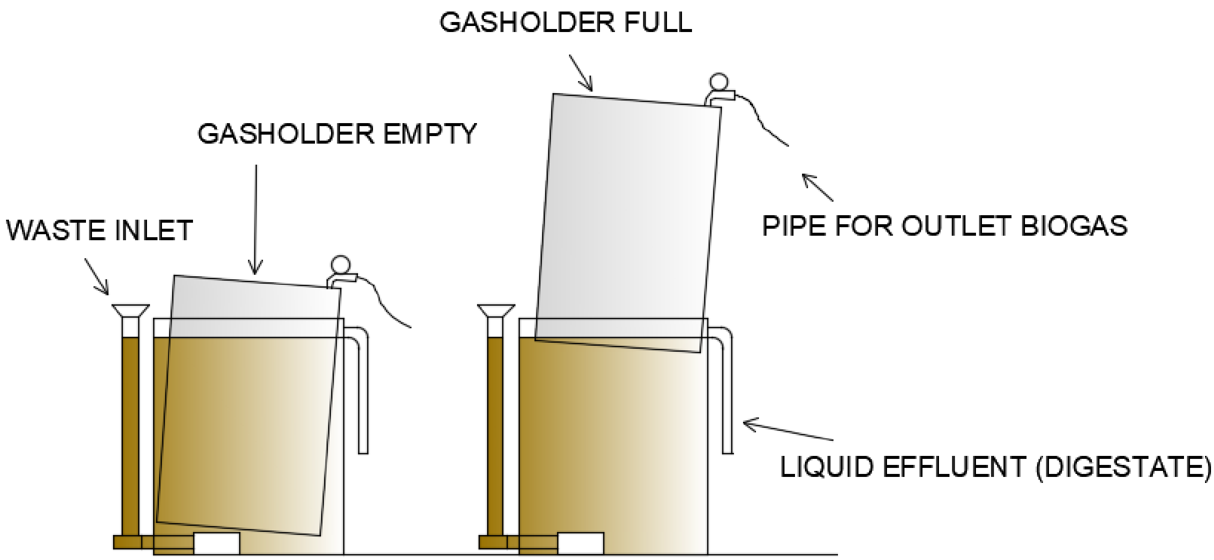


Figure 5 - Example of floating-drum digester with (a) gasholder empty and (b) gas-filled

The biogas produced will be used for domestic purposes, in particular in cooking stoves.

In general, the biogas produced with a domestic anaerobic digester varies as a function of several factors (e.g. temperature, type and amount of organic waste, and the quantity of water inlet). However, it is estimated that a Ghanaian family of five could produce enough biogas to use in their cook stoves, for about three hours per week.

Furthermore, the use of AD reduces the GHG emissions, as collecting and burning the biogas (which contains mainly CH_4), would help to mitigate the emissions.

In addition to the biogas, another valuable product is the liquid effluent (the digestate), a mixture of bacterial biomass and inert organics, from the digestion processes. The effluent from household digesters treating only kitchen waste (as in the Sustainable Livelihoods project) should be safe for reuse in the garden and for use as an organic fertiliser (Vögeli et al., 2014).

A potential limitation is that anaerobic digestion requires a regular supply of water every day. Consequently if the rural community involved has limited water available, it would not represent a viable option. Indeed, a digester for a family of five may require around 5-10 litres of water each day. However, this does not necessary have to be drinking water, as water from an open well or a river can also be used.

References

Brundtland, GH, 1987. Report of the world commission on environment and development: our common future. Oxford; New York: World Commission on Environment and Development.

Chartier, R, Phillips, M, Mosquin, P, Elledge, M, Bronstein, K, Nandasena, S, Thornburg, V, Thornburg, J, Rodes, C, 2017. A comparative study of human exposures to household air pollution from commonly used cookstoves in Sri Lanka. Indoor Air 27, 147-159.

Clasen, T, Smith, KR, 2019. Let the “A” in WASH stand for air: integrating research and interventions to improve household air pollution (HAP) and water, sanitation and hygiene (WaSH) in low-income settings. Environmental Health Perspectives 127 (2).

Cointreau, S., 2006. Occupational and environmental health issues of solid waste management: special emphasis on middle and lower-income countries. The World Bank, Urban Solid Waste Management, Washington, DC.

Couth, R, Trois, C, Vaughan-Jones, S, 2011. Modelling of greenhouse gas emissions from municipal solid waste disposal in Africa. International Journal of Greenhouse Gas Control 5 (6), 1443-1453.

Ferronato, N, Torretta, V, 2019. Waste Mismanagement in Developing Countries: A Review of Global Issues. International Journal of Environmental Research and Public Health 16, 1060.

Fiani, E, Karl, U, Umlauf, G, De Assunção, JV, Kakareka, S, Fiedler, H, Costner, P, Weber, R, 2013. Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs. UNEP (United Nations Environment Programme), Geneva, CH.

Jetter, JJ, Kariher, P, 2009. Solid-fuel household cook stoves: Characterization of performance and emissions. Biomass and Bioenergy 33 (2), 294-305.

Kumar, M, Kumar, S, Tyagi, SK, 2013. Design, development and technological advancement in the biomass cookstoves: a review. Renewable Sustainable Energy Reviews 26, 265-285.

Liao, J., McCracken, J.P., Piedrahita, R. et al, 2019. The use of bluetooth low energy Beacon systems to estimate indirect personal exposure to household air pollution. journal of exposure science and environmental epidemiology. doi:10.1038/s41370-019-0172-z

Miezah, K, Obiri-Danso, K, Kádár, Z, Fei-Baffoe, B, Mensah, MY, 2015. Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. Waste Management 46, 15-27.

Mihai, FC, Ingrao, C, 2018. Assessment of biowaste losses through unsound waste management practices in rural areas and the role of home composting. Journal of Cleaner Production 172, 1631-1638.

Ngwabie, NM, Wirlen, YL, Yinda, GS, VanderZaag, AC, 2019. Quantifying greenhouse gas emissions from municipal solid waste dumpsites in Cameroon. Waste Management 87, 947-953.

Parmigiani, SP, Vitali, F, Lezzi, AM, Vaccari, M, 2014. Design and performance assessment of a rice husk fuelled stove for household cooking in a typical sub-Saharan setting. Energy for Sustainable Development 23, 15–24.

Rehfuess, E, Pope, D, Bruce, N, Dherani, M, Jagoe, K, Naeher, L, Noonan, C, 2014. Review 6: Impacts of Interventions on Household Air Pollution Concentrations and Personal Exposure, WHO Indoor Air Quality Guidelines: Household Fuel Combustion. WHO, Geneva, CH.

UN (United Nations), 2015. Transforming our world: the 2030 Agenda for Sustainable Development. A/RES/70/1. Available online: https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (Accessed on 25/01/2020)

Urmee, T, Gyamfi, S, 2014. A review of improved Cookstove technologies and programs. Renewable and Sustainable Energy Reviews 33, 625-635.

Vaccari, M, Vinti, G, Tudor, T, 2018. An analysis of the risk posed by leachate from dumpsites in developing countries. Environments 5, 99. DOI: 10.3390/environments5090099

Van Fan, Y, Lee, CT, Klemeš, JJ, Bong CPC, Ho WS, 2016. Economic assessment system towards sustainable composting quality in the developing countries. Clean Techn Environ Policy 18, 2479–2491.

Vögeli, Y, Lohri, CR, Gallardo, A, Diener, S, Zurbrügg, C, 2014. Anaerobic digestion of biowaste in developing countries. Practical Information and Case Studies. Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, CH.

WHO (World Health Organization), 2010. WHO guidelines for indoor air quality: selected pollutants. World Health Organization. Regional Office for Europe. Available online: http://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf (Accessed on 25 January 2020)

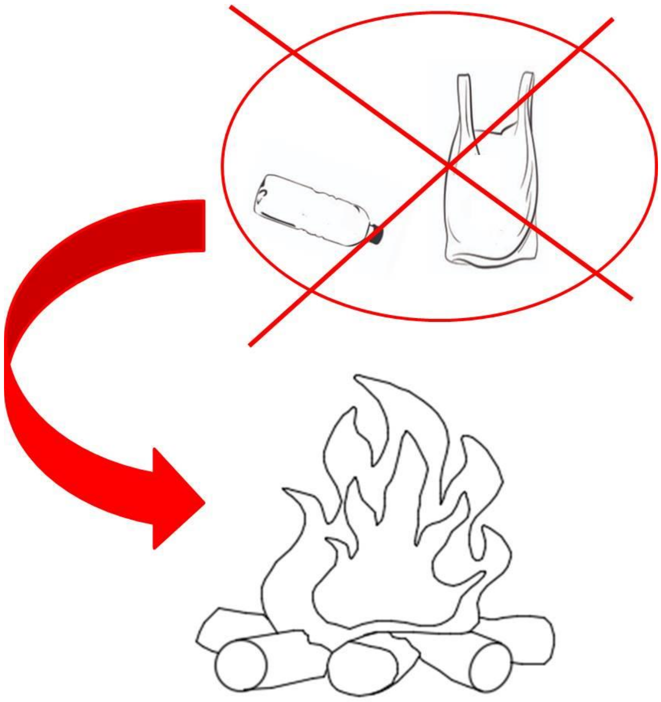
WHO (World Health Organization), 2014. "Ambient (outdoor) air quality and health: fact sheet". Fact sheet N°313. Available online: https://web.archive.org/web/20160104165807/http://www.who.int/mediacentre/factsheets/fs313/en/ (Accessed on 25 January 2020)

WHO (World Health Organization, 2019. Preventing disease through healthy environments: exposure to dioxins and dioxin-like substances: a major public health concern. World Health Organization. Available online: https://apps.who.int/iris/bitstream/handle/10665/329485/WHO-CED-PHE-EPE-19.4.4-eng.pdf?ua=1 (Accessed on 25/01/2020)

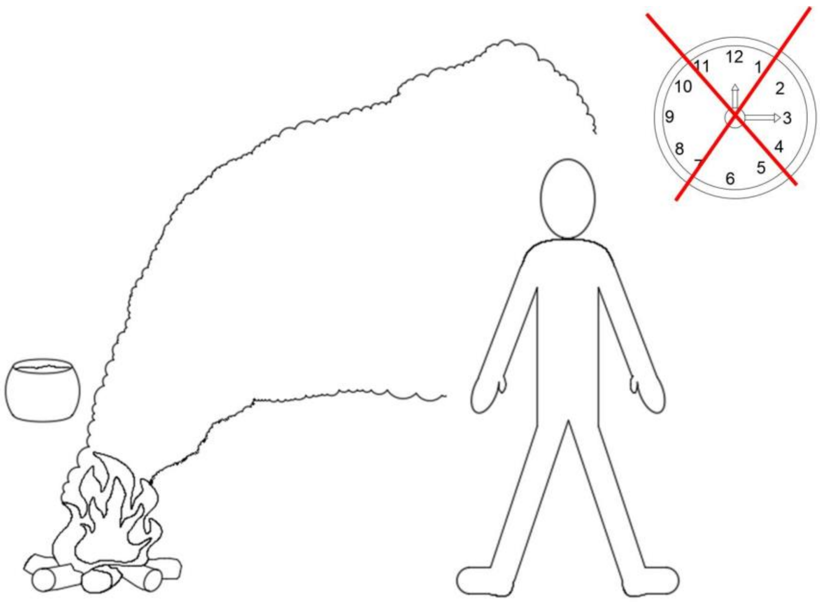
Annex – Best practice to reduce environmental and health risks

Cooking time

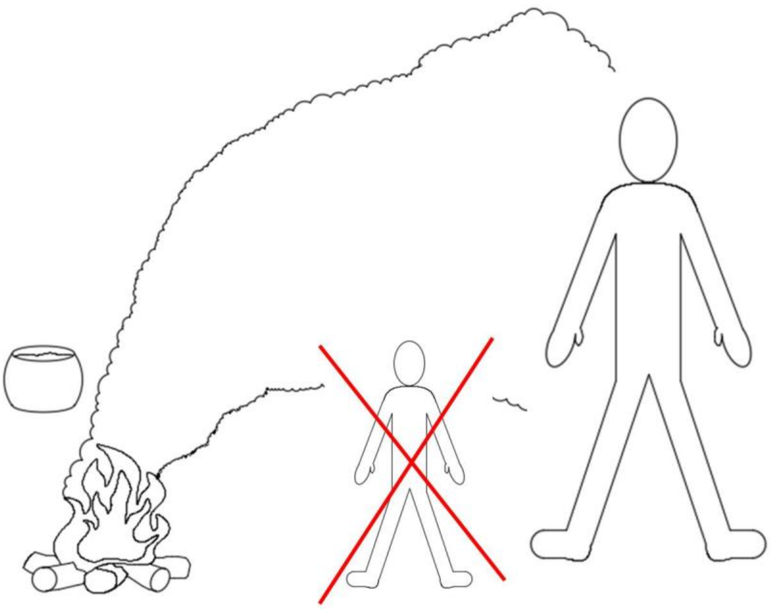
- **Do not use plastics as a fuel!**



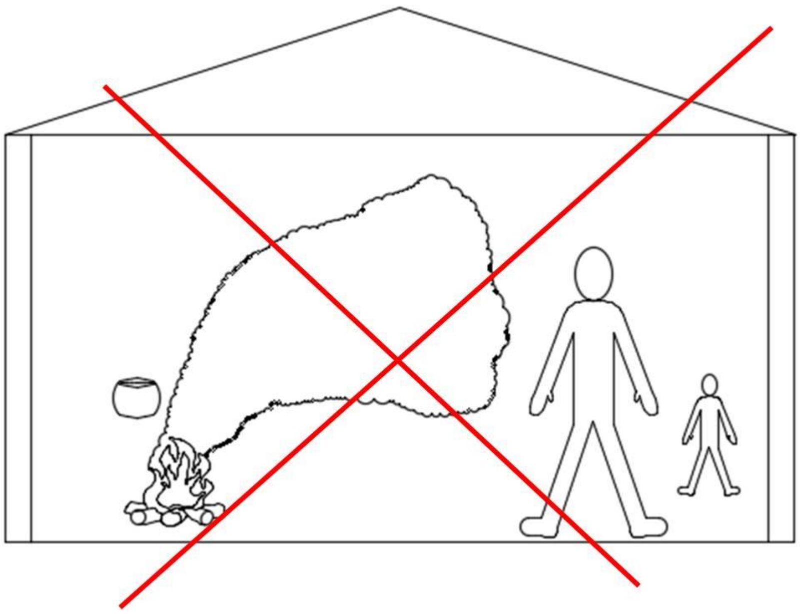
- **Do not spend too much time close to open flames and smoke**



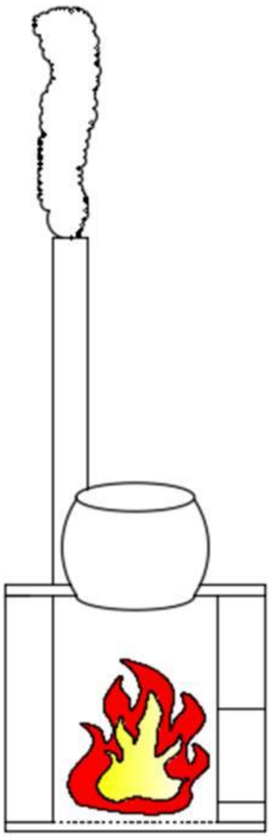
- **Keep your children away from smoke. They are the most vulnerable!**



- **If you are cooking indoors, in semi-closed or not well ventilated areas, improve air recirculation to reduce smoke concentration around you.**



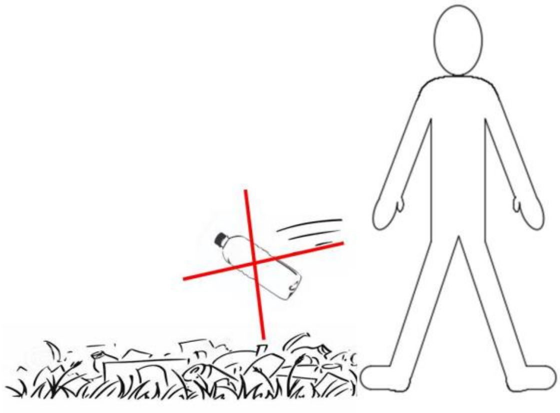
- **Use improved cookstoves (or floating-drum anaerobic digesters – *see solid waste management section*).**



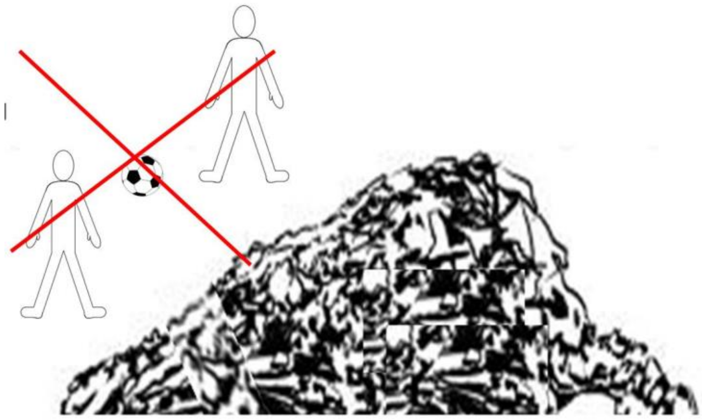
- **Do not burn solid waste. In particular do not burn plastics!**

- **Do not position dumpsites nearby inhabited areas. Where possible, use a landfill with protection (a waterproof layer at the bottom, a fence, a leachate drainage and treatment system), which is some distance away from inhabited areas.**

- **Do not litter! Ask for a waste collection system or at least arrange it at community level.**

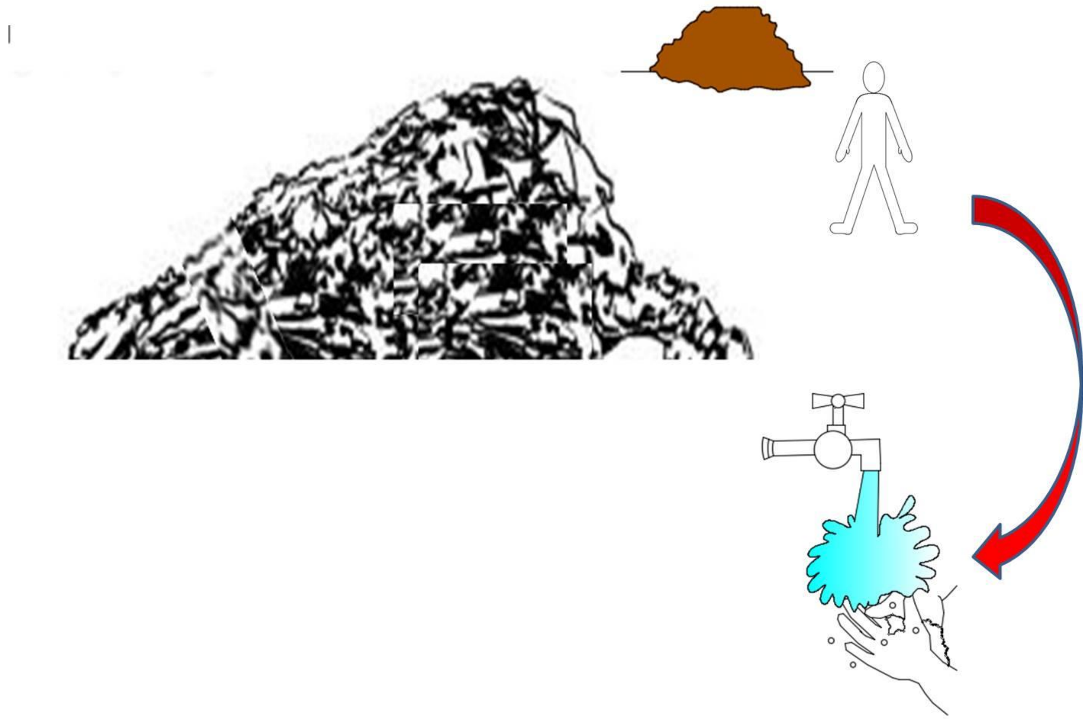


- **Do not spend time around dumpsites. In particular, do not allow children to play there!**

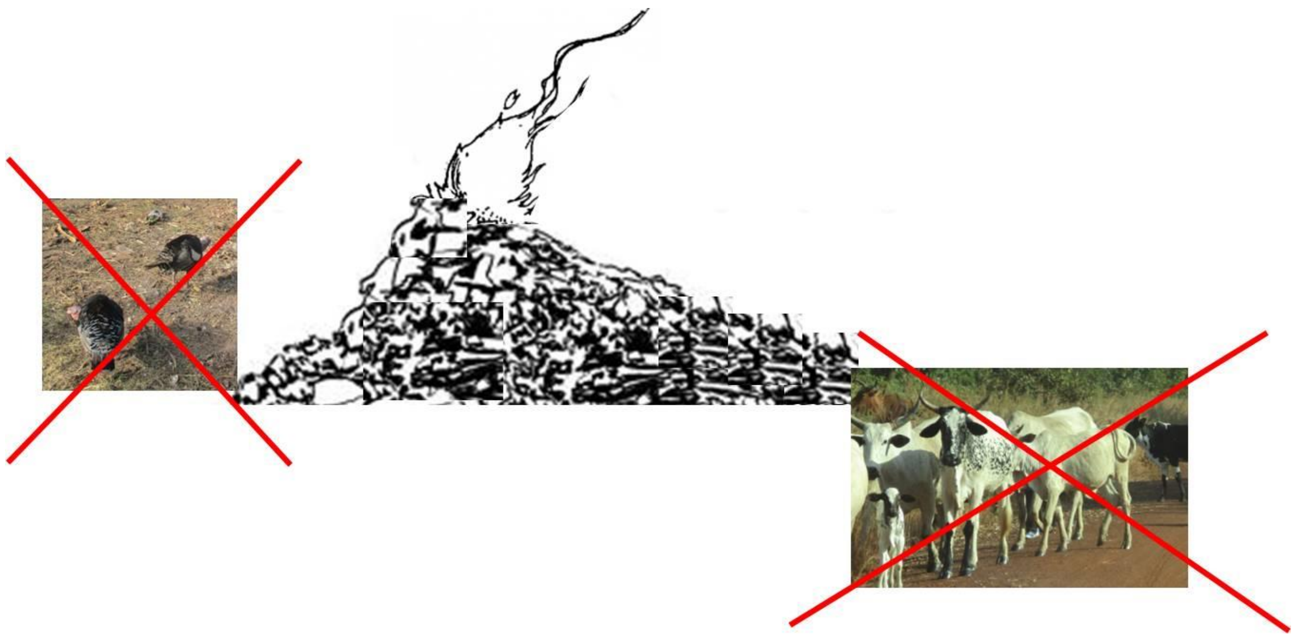


- **Do not build wells nearby dumpsites.**

- **Wash your hands (with soap if possible), if you touch garbage!**

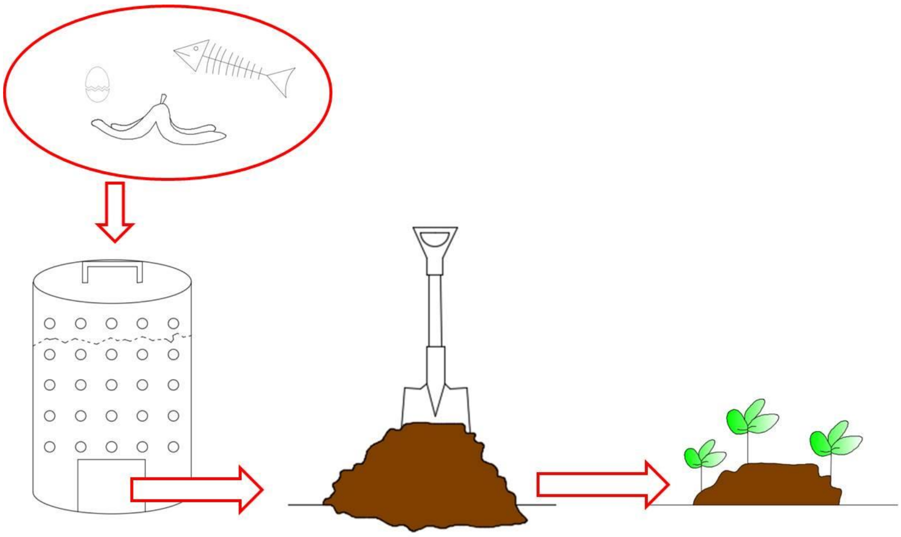


- **Do not allow animals to eat food from dumpsites and burned waste (for instance make a fence around existing dumpsites).**



- **Use your garbage as a resource. However, it is important not to mix organic waste with plastics, metals, glass or with ashes from the burning of waste. You could:**

  - ✓ **Make compost from your organic waste (such as green and food waste), using composting bins.**



  - ✓ **Make biogas from your food waste, using anaerobic digesters.**