Division 45
Rural Development

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Manual on Simple Monitoring Techniques for the Control of Indoor Air and Combustion Quality Standards in Developing Countries

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0. Introduction

Urban and rural households in developing countries depend mainly on traditional fuels like wood, dung or other biomass for energy. The use of traditional fuels in stoves and ovens, especially in those without chimneys, leads to substantial air pollution. This air pollution may cause serious and dangerous infections and diseases of the respiratory system.

According to estimates of WHO, 14,000 children, mainly from rural areas, die daily in developing countries on account of respiratory infections. There is a clear evidence that traditional biomass burning is a crucial and important contributing factor. The implementation of acceptable indoor air quality standards in traditional fuel using households is therefore an important element and challenge in the struggle for better human living conditions of children and their families in developing countries.

The experience of projects aiming at the improvement of traditional energy use has shown that standards on indoor air quality, device emissions, safety and efficiency are needed to avoid undesirable and to verify real progress in the field. Monitoring methods, which can be widely used in the frame of these projects need to be easy, simple to conduct and evaluate, cheap and time efficient. Regular sophisticated sensitive monitoring equipment as used in northern countries, is usually not appropriate. Many of these devices operate incorrectly under the climatical stress conditions found in tropical countries, where only little service options are available and, in addition, field workers have limited capabilities to operate and evaluate sensitive instruments and probes.

This manual intends to provide simple and economic methods for the definition of the various types of air pollution in such a way, that also non-professionals may be able to learn and apply these methods in a safe manner, and to identify and assess seriously polluted working places and living areas. It goes without saying that the recommended methods have their limitations in those situations, where high precision and accuracy is required. However, in more than 90 % of the investigations in traditional fuel using households the pollutant concentrations found where far beyond acceptable standards and often 10 to 100 times higher. These ranges of concentrations do not require the use of sensitive instrumentation, which may even be counterproductive, because those instruments are likely to misoperate or even completely fail under such circumstances.

In any case, highly accurate and precise data for the purpose of epidemiological studies are generally not feasible in the frame of most development projects, as those studies are extremely costly and so time-consuming that generally it requires years of work before any conclusions can be drawn on the effects of certain pollutant concentrations.

Therefore, projects and institutions should concern themselves only with objectively demonstrating apparent air pollutions by simple methods which are able to present a rough quantification of data. In those cases where the limits found are too low to be detected with the proposed methods, it is advisable to involve a specialist to verify the range and impact of the detected concentrations because there is no guarantee that minor pullution concentrations do not bear serious health risks.

About the manual

The first chapter shows and explains the various techniques of air measuring and the major polluting substances.

The methods of air measuring described in the manual are based on the fundamental principles approved by international and national laws, as described in the second chapter, where air pollution standards are described for soot, carbon monoxide, carbon dioxide and other types of gases.

Since air pollution is caused by the combustion process within the fireplace, the efficiency of this process is decisive for the assessment of the stoves and parameters explained in chapter three.

Chapter four explains the basic principles of exposure measuring like position, duration and spreading of dangerous substances in a room.

Chapter five deals with the most simple and economic measuring methods.

Chapter six gives practical advice on air measuring procedures, starting with the preparation, calibration, the implementation up to the evaluation of the measured quantities.

Appendix A provides readymade checklists for the practical preparation of the proposed monitoring methods.

Appendix B provides a summary of sample protocols necessary during field work.

Appendix C and D supply background materials for stove testing and statistical survey methods.

Appendix E and F contain a bibliography and indices.

1.0 Definition of Terms

Concerning an air measuring technique it is important to use alike and clearly defined terms. Only by this it is possible to compare a measuring report from Africa with one from Latin America.

1.1 General Terms in Air Measuring Techniques

The burning of wood, dung, straw and other biomasses produces toxic combustion gases, like for instance carbon monoxide and formaldehyde. These gases pollute the breathing air of those persons near the fire place.

The concentration of toxic substances is at its highest in the direct vicinity of the firing zone or ovens.This toxic concentration diminishes by its rarefaction with the surrounding air as the distance from the fire place increases. Tightness and ventilation determine the concentration of toxic substances in the case of closed stoves.

Here follows a short description of the most important terms.

Pure air:

Natural dry air is a gas mixture consisting of 78% nitrogen, 21% oxygen, 0.03 Vol. % of carbondioxide as well as of argon, helium and other rare gases in trace concentrations.

Air pollution

Air pollution is caused by changes in the natural composition of the air, especially by smoke, soot, dust, gases, aerosols, vapours or odorous substances. Steam may also be part of the vapours.

Dust particles	are solid substances in the air
Vapours	are liquid substances in the air
Aerosols	are finely distributed solid and liquid substances hovering in the air.

Emissions

Emissions are the air polluting agents released by a combustion source. The results of the emission measurement can also be used to examine improvements of the combustion process. Emission measurements are taken directly at the fireplace or in the exhaust chimney. The concentration of air pollutants encountered in emission measurements is always higher than the one found in exposure measurements.

Concentration

The concentration of air pollutants in the air depends above all on the emissions but also on the prevalent atmospheric conditions (or ventilation if measured inside a building). Air pollutant concentration will decrease in relation to the distance from the emission.

Exposures

When air pollutants affect people, animals or plants, we talk of exposure. Exposure measurements assess the concentration received by the acceptor, for instance in the oral and nasal cavities of the cook working at the cooking stove.

Dose

'Dose' measures how much pollutant is actually inhaled by an acceptor and depends not only on the grade of exposure but also on such factors as the rate of breathing and the size of the particles.

Health effect, health risk

Health effects depend not only on dose but also on age, sex, whether the person smokes and the existence of other diseases.

The pollution of air with particles that enter the pulmonary tract, like carbon monoxide, nitrogen oxide and other toxic gases leads to respiratory diseases such as bronchitis and pneumonia. In addition, hemaglobin values in the blood change. It may lead to cancer, heart attack and pulmonary infections.The immune system is affected. Pollutants affect children in a higher degree than adults.

Air pollutants

During the combustion of biomass the following measurable pollutants, which may be used to estimate health risks, are normally released,. (See also chapter 1.2).

Carbon monoxide CO
Hydrocarbons CmHn
Nitrogen oxides NOx
Sulphur oxides SOx
Soot, dust and particles
Formaldehyde HCHO

Air exchange rate

All toxic gases released during the combustion process are decomposed and neutralized in the air.They will be decomposed or mixed with fresh air for a certain period of time until their concentration can no longer be demonstrated. The air exchange in the room under examination, e.g. the kitchen air with the ambient air, can be analyzed through this mixture.

1.2. Formation of Pollutants during the Combustion of Biomass.

The most important pollutants released during the burning of wood, other biomass and such fossil fuels like coal, gas or kerosine, are particles, hydrocarbons, carbon monoxide, nitrogen oxide, sulphur oxide and formaldehyde.

Naturally type and quantity of the emitted pollutants depend on the fuel used and the type of stove.

Table 1 shows estimated emission factors of wood, cowdung, coal, charcoal and natural gas.

Fuel	Heating Value (MJ/kg)	TSP d<10###m (mg/m^3)	CO_2 (Vol.-%)	CO (mg/m^3)	C_mH_n (ng/m^3)	NO_2 (mg/m^3)	SO_2 (mg/m^3)
Wood	16	4-20	8	12-156	1300	0,31	0,16
Dung	12,5	5-80	-	17-175	8200	0,14	0,24
Charcoal	30	5,5	-	-	-	0,075	0,83
Coal (Indien)	23	24,9	-	-	4200	0,17	1,7

Table 1: Expected concentrations from various biofuel uses [1]

Total Suspended Particulates (TSP)

In case of biofuel combustion these particulates typically consist of soot and tars. Soot consists of finely distributed carbon with a low and varying hydrogen and oxygen content and hydrocarbon compounds (e.g. tars).

Primarily the fine dusts, especially the inhalable particulates, smaller than 10 µm in diameter and the respirable particles, smaller than 3 µm, are considered to be a health risk.

Hydrocarbons (CnHm)

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[1] K.R. Smith Biofuels, Air Pollution, and Health, 1987, New York

develop as cyclic or polycylic matters during any combustion process involving carbon and hydrogen. In relation to their boiling point, hydrocarbons occur either as aerosols or as gases in the combustion air.

The most frequently measured hydrocarbon substance is benzoapyrene, which is used as indicator for an entire group of hydrocarbons. In addition to benzoapyrene, over 200 different hydrocarbon molecules occur during the burning of biomass. Most hydrocarbons are suspected to be carcinogenic.

The volatile hydrocarbon content in the air may be measured e.g. by means of test tubes. Instead of determining the separate components, these methods generally focus on the total of volatile hydrocarbons.

For an exact determination of the distribution of single components, e.g. the amount of benzolpyrene in the air, samples are analyzed with the aid of a gaschromatographer.

Carbon monoxide (CO)

is a combustible, colourless, odourless and highly toxic gas. It is released during the combustion of fossil and biofuels. The more complete the combustion proceeds (depending on the availability of sufficient air), the bigger the CO_2 content and the smaller the CO content. Thus the CO_2 content represents a rate for the quality of combustion (see chapter 3).

Once carbon monoxide has been respired it gets to the blood through the lungs there preventing the reception of vital oxygen. The affinity of human blood to CO is 200 times higher than that to oxygen. Thus a small amount of CO in the blood can lead to the situation where the blood is no longer able to take up oxygen.

In addition to the firing of stoves with wood, dung or straw, the combustion of diesel and petrol in road traffic presents the major cause for the emission of CO.

The occurrence of CO is measured by means of electronic manual monitoring devices (chapter 5.6) , by test tubes or directly in the blood.

Sulphur oxides (SO, SO_2)

are mainly generated during the combustion of fossil fuels. As far as wood, (containing hardly any sulphur) is concerned, sulphur oxides do not play an important part. Their occurrrence is more important during the combustion of dung.

Sulphur, as a component of fuels, occurs primarily in coal, petrol, kerosine and diesel. SO_2 serves among more than 1000 air pollutants as the most important indicator for air pollution. The existences of sulphur oxide in the air leads to irritations of the mucous membranes and of the eyes, as well as to chronic bronchitis.

Sulphur oxide SO and SO_2 can be measured with the aid of test tubes (chapter 5.6) or by portable devices containing electronic sensors for digital readings (chapter 5.7).

Formaldehyde (HCHO)

is a colourless, pungently smelling gas. HCHO leads to chronic respiratory diseases. Although formaldehyde does not naturally occur in wood, it is contained as a chemical additive in many building materials, e.g. to impregnate wood. During the burning of several biofuels, especially dung, substantial emissions of HCHO are released. (K.Smith, 1989).

Nitrogen oxides (NO, NO_2, NO_3)
occurs mainly as a result of high temperature combustion. Therefore it is less of a problem concerning biofuel burning since most combustion techniques work at relatively low temperature (below 1000°C). It is important however while monitoring the impact of kerosene and gas stoves.

1.3 Quantities and Units of Measure for Exposure and Emission Monitoring

Since very small accumulations of the described pollutants are enough to cause health risks, the concentrations that are to be measured in case of air pollution are also very small. They are either indicated in volume parts or in mass per volume of air.

Units of volume concentration are expressed in ppm (1 part per million = 0,0001 %). For mass concentration mg/m^3 is used. The value in ppm equals the value in ml/m^3.

1 Vol.-% = 10 000 ppm = 10 000 ml/m^3

Equation 1: Correlation Volume percentages and ppm.

Since condition factors like pressure and temperature have to be considered while converting ppm into mg/m^3, 20°C and 1013 mbar have been determined as basic reference condition.

The molvolume of any gas is 24,l/mol at 20° C and 1013 mbar. Temperature and air pressure are of no importance for the conversion of ppm into mg/m^3, since the total volume of 1 m^3 is described by value ppm as volume content and value mg as weight content. Equation 2 shows the conversion mg/m^3 into ppm, equation 3 the conversion ppm into mg/m^3 as shown in table 2.

Value in ppm [ml/m^3] = Value in mg/m^3 x 24.1 l/mol / components mass of mol (in g/mol)

*Equation 2: Conversion of mg/**m³** into ppm.*

Value in mg/m^3 = Value in ppm[mg/m^3] x components mass of mol (in g/mol) / 24.1 l/mol

*Equation 3: Conversion of ppm in mg/**m³***

After having determined the mass of mol of a certain matter with the aid of a periodic table of the chemical elements, further conversion factors will be easy to calculate.

The conversion factors ppm into mg/m^3 and vice versa are listed in table 2.

Gas	Mass of mol (g/mol)	Factor to convert ppm into mg/m^3	Factor to convert mg/m^3 into ppm
Carbon monoxide CO	28	1.16	0.86
Nitrogen dioxide NO_2	46	1.91	0.52
Sulphur dioxide SO_2	64	2.66	0.37
Formaldehyde HCHO	30	1.25	0.8
Benzol C_6H_6	78	3.25	0.31

*Table 2: Conversion factors of different substances ppm into mg/**m³** and vice versa*

As an example:

1) A carbon monoxide content of 10 mg/m^3 was measured. This value corresponds to 0,86 x 10 mg/m^3 = 8,6 ppm
2) The measured value of formaldehyde 0,3 ppm corresponds to 1,25 x 0,3 ppm= 0,375 mg/m^3.

2.0 Basic Principles for Air Quality Standards and Regulations

In all northern industrial countries a set of rules regulates the cleanness of the air and the monitoring of pollutant exposure and emission. Moreover global organizations like e.g. UNIDO or WHO have issued their own standards.

Usually, the administrative regulation of the air pollution control system runs under the federal law for exposure protection. This regulation, as laid down in the technical manual for keeping the air clean, represents a fundamental document for the definition of terms above, the determination of carcinogenic substances and the restriction and determination of emissions. It serves to protect the general public in the respective countries from harmful environmental effects caused by air pollution.

In order to check and determine airborne pollutants from combustion sources, measurement procedures should be conducted on the stoves/heaters/ovens and the surrounding area. To organize the great variety of measurement possibilities in a sensible, uniform and comparable way, general guidelines have been drawn up by national organizations and associations of engineers (e.g the ooccupational Exposure Limits 1993, the TRGS 900, the VDI-guidelines, the Treshhold Limit Values (TLV) by the American Conference of Governmental Hygienists (ACGIH), Cincinnati 1992, and others OSHA, COSHH).

The legal limits for pollution measurement can be set at national or regional level, depending on typical respective applications for analyzing various working place situations or to authorize products or production processes, which are in compliance with the agreed limits. For the introduction of improved stoves for example, regional or national authorities should formulate legal standards in terms of emissions, safety and efficiency, which new models have to comply with. With the help of simple monitoring equipment, those standards could be widely applied and so help to improve and control the quality of the stoves.

Guidelines in this manual could provide instructions for exposure and emission monitoring in such a way, that both could be conducted and analyzed under conditions typically found in industrially less developed countries. Appropriate standard quantities could thus be deducted from the monitoring data for comparison with legal limits.

The presented limits however, are based on the various experiences with pollutant concentrations and representative standards, at which level health risks have been clearly proven. Consequently there can be no guarantee for lower levels automaticallly providing trouble free working environments. Therefore pollution concentrations should always be kept to the lowest possible level.

In the following a list of limits issued by the WHO for relevant gaseous pollutants is presented. Usually most of the regulations differenciate between short-term and long-term limits. The ACGIH for example gives the following definitions:

TLV- Time Weighted Average ((TLV-TWA), the time weighted average for a normal 8-hour workday and a 40-hour workweek.
TLV - Short-Term Exposure Limit (TLV-STEL), the concentration to which workers can be exposed continously for a short period of time without any suffering
TLV- Ceiling (TLV-C), the concentration that should not be exceeded during any part of the working exposure.

Table 3: Health-affecting limits according to WHO Standards.

Pollutant	**Concentration**	**Time limit**
Carbon monoxide	100 mg/m^3 60 mg/m^3 30 mg/m^3 10 mg/m^3	15 min 30 min 1 hour 8 hours
Formaldehyde	100µg/m^3	30 min
Lead	1 µg/m^3	1 year
Nitrogen dioxide	400 µg/m 150 µg/m^3	1 hour 24 hours
Ozone	200 µg/m^3 120 µg/m^3	1 hour 8 hours
Sulfur dioxide	500 µg/m^3 350 µg/m^3 125 µg/m^3	10 min 1 hour 24 hours
Suspended Particles	120 µg/m^3	24 hours
Thoaric Particles	70 µg/m^3	24 hours
Benzene	2.5 µg/m^3	1 year
Asbestos	500 fibers/m^3	1 year
Radon	100 Bq	1 year
Tobacco smoke	as little as feasible	non inside young children or sick persons bedrooms

3.0 Combustion and Combustion Products of Solid Fuels

3.1 Biofuel

The term ‘biofuel’ is used to indicate the energetic exploitation of renewable resources in the form of wood or agricultural wastes like straw, nutshells, dung etc.

Charcoal is an upgraded biofuel.

Gas, coal and kerosine are fossil fuels.

Table 4 shows some of these fuels with their chemical composition. It also reveals that carbon is the decisive energy vehicle and that fossil fuels have a significantly higher sulphur content than biomass fuels.

Material	C	H	N	S	O
All data in percent weight					
Charcoal	80.3	3.1	0.2	0	11.3
Wood (hickory)	49.7	6.5	0	0	43.1
Rice huills	38,5	5.7	0.5	0	39.8
Dung	42.7	5.5	0.3	0.3	31.3
Anthracite coal	85	3	1	1	2
Diesel	86	13	0.5	0.5	0.4

Table 4: chemical components of fossil and biofuels 3)

3) from S. Baldwin , Biomass Stoves and Taschenbuch für Klima und Heizungstechnik (Paperback on Climate and Heating Techniques)

3.2 The Burning Process of Biomass

The burning process of wood and other biofuels is a complex one. It can be roughly subdivided into the following phases:

Phase 1: The water existing in the wood is released at a temperature of 100°C
Phase 2: At 200°C up to 300°C cellulose falls apart and the lignin[2] turns into carbon.
Vaporizing gases develop.
Phase 3: The vaporizing gases mix with oxygen at a temperature of about 550°C
producing a yellow flame.
Phase 4: Above the wood the hot gases reach a temperature of around 1000°C.

An abrupt cooling of the hot gases during phase 4, for instance by a cold pot or wind, lowers the burning temperature, thus creating incomplete combustion products.

A porous carbon layer develops on the outside surface of the burning wood. This carbonized layer acts on the gases as a catalyst, making the carbon dioxide react with the carbon in the wood turning into carbon monoxide. Some millimeters away from this surface the carbon monoxide reacts with oxygen turning into carbon dioxide. The temperature in this area is around 800°C. When the total amount of carbon has been burnt, mineral salts remain as ashes.

In order to burn 1 kg of wood the entire process requires approximately 5 m^3 of air. In the case of charcoal the relation is 9 m^3 of air to 1 kg of charcoal.

Discontinuous combustion process

Combustion is not a continuous process. Due to a lower processing heat, considerably more CO and carbonhydrates are emitted at the beginning and at the end of the burning process. The opposite occurs for the emission of CO_2: it reaches its highest value during combustion.
Combustion is classified into three phases:

1. production of the first embers,
2. completely developed burning phase
3. cooling down phase.

3.3 The Influence of Combustion Efficiency, Stove Technology and System Operation on Emission and Exposure.

Basically the emission of pollutants depends on the combustion quality and quantity of combusted fuel. Depending on where the emission environment is located, quantity and quality of fuels contribute to the level of expositions. The levels of combustion quality and fuel efficiency are expressed by the following three dimensions:

• degree of complete combustion	(combustion efficiency)
• efficiency of the stove/oven	(technical efficiency)
• efficiency of the system operation	(system efficiency)

Combustion efficiency is influenced by the fuel quality and the combustion chamber characteristics of a stove. A simple determination of the combustion efficiency is done with the help of the CO/CO_2 ratio (described in chapter 4.1).

The **stove efficiency** is influenced by the materials, the constructive perfection and dimensions which are used to force heat transfer to the pot. It is measured by the energy utilized (*mass of food x degrees food heated x*

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[2] The compounds of the elements carbon (C), hydrogen (H) and oxygen (O) form the major components of the biofuels cellulose and lignin.

specific heat of food) in realtion to the energy input (*mass of fuel x heating value*), under standardized, controlled operational conditions. There are basically two test procedures, the water boiling test and the standard meal test. Both test protocols, procedures and calculations can be found in annex B.

The **system efficiency** depends on the system operator's capabilities to economize the fuel consumption through optimized food, pot, stove and fuel handling. System efficiency measures the relation of energy input to energy utilized, without influencing or standardizing the individual influence of operators. The system efficiency is usually determined either through kitchen performance tests or fuel consumption tests. Both test protocols, procedures and calculations can also be found in annex B.

4.0 Principals for Exposure and Emission Measurement

This chapters addresses the fundamental principles of air measurement technique. The spreading of indoor pollutants determines the location of the measurment equipment. The most important me-thods for measuring different pollutants is described. Generally used formulars are shown for the evaluation of the ascertained data.

Test Area	Emission	Exposure
Concentration present in the waste gas	high	low
Gas sampling to be drawn in	low	high
Measurement duration	short	long
Measurement expenditure	low	high

Table 5: Principal differences between emission and exposure measurements

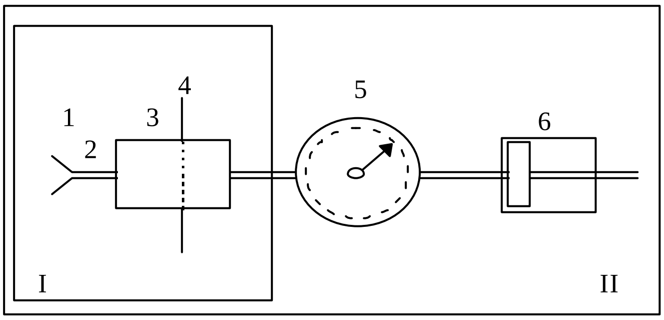
Simple measurement methods can be applied only in cases where the results clearly exceed or fall below the limits. This is for instance the case for typical TSP concentrations found in rural indoor kitchens with open fireplaces.

The choice of monitoring techniques and equipment depends on analysis and monitoring conditions. The following monitoring principles will therefore be combined according to necessity:

Monitoring Principle	Explanation
Contineous (real time)	Continuous monitoring with actual course of concentration
Integrated	Discontinuous, punctual monitoring in variable time distances and phases
Grab or spot	Separate, punctual monitoring e.g. for determining maximum and minimal values
Time-weighted average	Mean obtained from the total of all measurement results, related to the monitoring time
Area	is used in the case of permanently installed monitoring equipment, e.g. for area surveillance
Personal	is used when individual exposures of one person at different locations and times are to be measured
Passive sampling	Monitoring without active collection of waste gas
Active sampling	Monitoring with the aid of active waste gas collectors, e.g. vacuum pump
Field monitoring	Monitoring in the field, e.g. in the kitchen under daily circumstances
Laboratory monitoring	Monitoring at the laboratory, controlling all parameters

Table 6: Monitoring principles

Each monitoring device is basically composed of the following parts:



I Passive Sampling Setting
II Active Sampling Setting

Figure 1: Basic set up of monitoring equipment

1. Sampling probe
2. Air-drawing tube
3. Separating device
4. Device for measuring pollutants
5. Volume monitoring
6. Pump unit

The interior box describes the monitoring device for passive monitoring, whereas the entire device is meant for active measuring.

In the case of passive monitoring two quantities are measured:
- Amount of pollutants
- Measurement time

Active monitoring is based on:

- Amount of pollutants
- Measurement time, and
- Flow of waste gas volume.

The amount of pollutants (as a rule mass concentration) is the output of:

Indicated amount of pollutants / measurement time x flow of waste gas volume

Equation 4: Amount of pollutants

The concentration of pollutants is expressed in g/m^3, mg/m^3, ug/m^3 or in rare cases also in cm^2/m^3. PPM or PPb (Parts per million/billion) are obsolete quantities. A survey of quantities used in emission and exposure monitoring is shown below:

Quantity	Unit	Explanation
Mass concentration	g/m^3 mg/m^3 $\mu m/m^3$ ng/m^3	Mass of air pollutants related to the waste gas volume in standard condition (20°C, 1013 mbar)
Volume concentration	cm^3/m^3	Volume of air pollutants related to waste gas volume old: ppm = 1 cm^3/m^3 (volume ppm) or 1 mg/kg (mass ppm)
Mass flow	g/h	Mass of air pollutants related to time
Emission factor	kg/MJ mg/kg	Mass of air pollutants related to the heating value of fuel Mass of air pollutants per kg of fuel used.
Sediment concentration	$g/(m^2x\ t)$ $mg/(m^2xt)$	Sedimented dust related to the dusted surface and to time.

Table 7: Quantities of emission and exposure monitoring

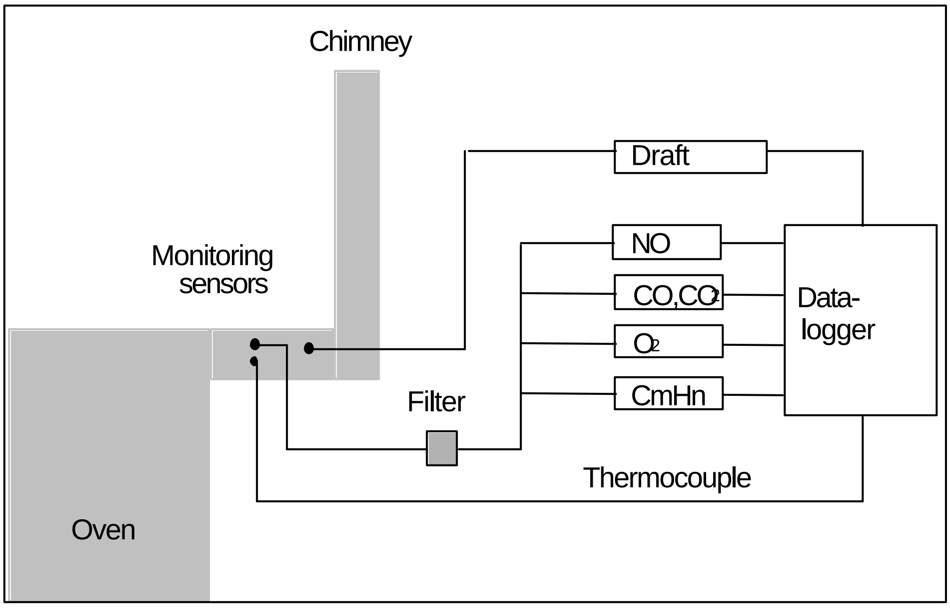
4.1 Emission Monitoring

Emission monitoring is used for the qualitative and quantitave determination of pollutant-emitting sources. The following description refers to combustion technologies for biomass, normally used in households in developing countries. The most important sources are open cooking stoves (without chimneys), fireplaces and closed stoves with chimney.

4.1.1 Sampling Location in Cooking Stoves with Chimneys

For measuring the quality of combustion monitoring, probes are applied to the stove chimney. Complete monitoring requires the measurement of gases as well as the temperature and possibly the draught in the chimney. Figure 2 illustrates such a test in a schematic way.

Figure 2: Monitoring of cooking stove with chimney [3]



Sampling for determining the concentration, waste gas temperature and chimney draught is performed at the point between stove and chimney. The toxic gases determine the concentrations of carbon monoxide (CO) and the total of carbonhydrates (CnHm). To calculate the turnover of fuel, the concentration of carbon dioxide (CO_2) will be measured.

To convert the measured pollutant concentrations into a uniform oxygen content (O_2), the oxyen concentration in the waste gas can be measured.

4.1.2 Sampling from Open Stoves

Sampling from open stoves is more difficult, because there is no defined standard. Sampling can be done by either collecting the gases with the help of a exhaust hood (which may influence the stove performance in some cases) or by measuring in the main exhaust stream of the stove (e.g. at the height where the pot is situated).

To avoid measuring mistakes it is advisable to cool down the waste gases prior to entering the sampling probes for carbon monoxide (CO) and oxygen (O_2) for the steam to vaporize. Regarding the sampling probes for carbonhydrates (CnHm) waste gases should be heated to such a point, that the liquid carbonhydrates will stay in the air as aerosols.

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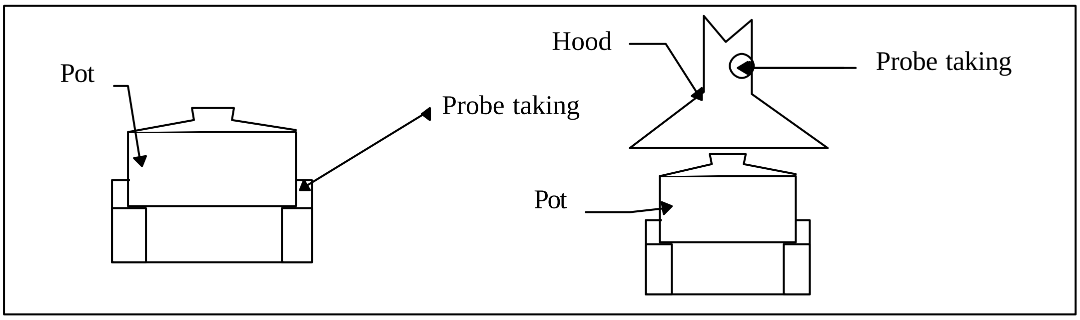
[3] 5) from M. Struschka: Pollutant emissions of wood briquettes and firewood - Stuttgart 1992

Figure 3: Emission monitoring at open stoves



CO_2 can be measured instantaneously with tubes, as well as with the aid of CO and O_2 concentrations.

For a basic assessment of the combustion quality of stoves one can either apply the ratio:
Mass of pollutants related to the mass of burnt fuel, or the ratio between CO and CO_2.

$CO/CO_2 << 0,1$

The value should be smaller than 0,1; 0,02 e.g. represents a good value.

Typical burning values for fuelwood cooking stoves are e.g.:
44 g/kg CO
10 g/kg total hydrocarbons

Other important combustion parameters can be determined with the aid of the O_2 measurement:

- Energetic loss of waste gas
- Excess air

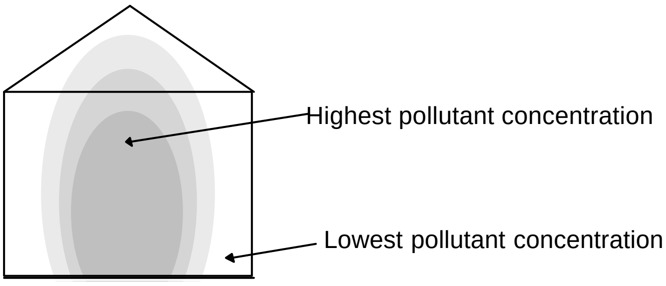
4.2 Exposure Monitoring - Spreading of Pollutants

The exposure monitoring should determine the kind, intensity or duration of the exposure and its influence on people. Generally pollutants from domestic cooking are released from a point-shaped source. The distribution and consequently mixing of the pollutants occurs by diffusion, convection and air flow. In traditional huts these 3 processes cause generally pollutants to spread in the shape of a elipsoid, whose base lies in the source of pollutants.

This principal shape of extension is influenced by factors such as:

- exhaust gas temperature and volume
- ventilation or wind conditions
- humidity
- architecture of the house (height, size)

Figure 4: Likely scenario of expansion of indoor concentration of pollutants in a low ventilated village hut.



4.2.1 Sampling Location for Exposure Monitoring

The particular construction of the cooking stove, which determines e.g. the location of the flue at the fire-place, is very important in exposure monitoring. Also the working-process and the working-place should be determined.

Sampling is done at breathing organs-level, thus determining the exposure of the person working at the fire-place. In the case of test tube-monitoring it is advisable to attach the tubes directly to the clothes.

4.2.2 Length of Monitoring

There are basically two monitoring time frames:
- short-term measurement
- long-term measurement

Short-term measurements with test tubes usually require a time span of 10 seconds up to 15 minutes, whereas long-term and diffusion tubes are employed for measurements between 2 to 8 hours.

5.0 Instrumentation and Application

Basic monitoring methods like determining the weight by weighing, the temperature with a thermometer, the air humidity with a hygrometer, the air pressure with a barometer along with the specific heat capacity of the fuel, describe the conditions of the surrounding area of the air pollution that is to be analyzed.

For the small scale air measurement of biofuel stoves in developing countries the adsorption tubes and the Bacharach method are the most simple and economic methods.

5.1. Measurement Quantities for Determining the Gas Condition

5.1.1 Air Pressure Measurement

Air pressure measurement is done in the first place to determine the conditions of the surrounding area. It allows the comparison of various outputs at different locations.

Air pressure can be read directly in bar with the aid of a barometer or calculated from the known altitude. As shown in table 8, the air pressure changes according to the height of the location above sea-level.

Height in m	0	500	1000	2000	3000	4000
Air pressure in bar	1013	955	899	790	701	616

Temperature °C	15	11.8	8.5	2.04	-4.5	-11

Table 8: Decrease of air pressure and temperature in relation to height

5.1.2 Air Humidity and Fuel Humidity

The measurement principle is based on the changing of length of one single hair under the influence of humid air. This grade of humidity can be easily measured with a regular hygrometer.
With the help of the relative air humidity it is possible to deduce the relative humidity of air-dried biomass fuels, provided these have been stored long enough and the daily air humidity changes only slowly. This is especially the case in dry countries with a steady climate.

The air humidity content of the fuel can then be approximated/equated to the air humidity and
the dry weight can be calculated as follows:

Dry weight biomass = $1- (1/(1+RH)$
RH =relative air humidity

There are also a number of digital monitoring devices in the market, which allow instantaneous reading of the humidity of biofuels.

In the case of devices with a direct readout, the monitoring probe is applied or stuck into the fuel after which the corresponding humidity can be read. This method has, however, also its limitations, since humidity in the wood may vary from inside to outside and the monitoring device has to be adjusted precisely to the corresponding type of wood.

Weighing the fuel is more accurate, less expensive but more time-consuming. The water content is determined by the weight loss of the fuel in a drying-process around 120°C during 2 (hot air oven) to 6 (normal electric oven) hours. This method requires narrow, quick-drying pieces of wood.

$$\mathbf{M(\%) = 100\,(Ww - Wd)\ /\ Wd}$$

Equation 5: Water content in fuel

M = water content in %
Wd = weight of dry fuel in kg
Ww = weight of original fuel in kg

5.1.3 Temperature Measurement

Simple temperature measurements can be done with mercury thermometers ranging from 35°C up to 300°C, indicated on a scale.

Digital temperature measurement devices are easy to use. They are based on the indication of an electric tension, caused either by a temperature-increased resistance within a metal wire or by the different tension of two touching metals.

5.2 Mass Determination

Mass determination is necessary for testing the technical and combustion efficiency as well as for the gravimetric determination of particles.

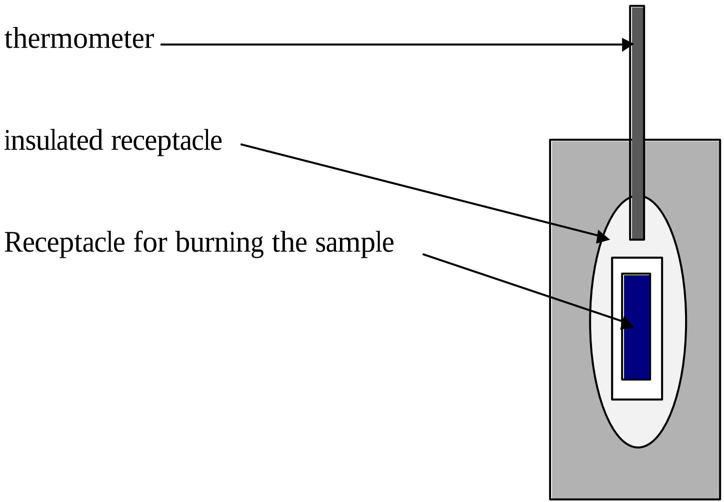
For determining the fuel weight in order to determine the technical as well as the combustion efficiency, a balance with a range up to 30 kg and a precise gram-indication is usually employed.

For gravimetric determinations of particle filters an analytical balance with an accuracy of 1 µgm (minimum accuracy 10 µgm) should be employed.

5.3 Determination of Heating Value

Determination of the energy content of fuels can be done with the aid of caloriemeters. As shown in figure 4 a fuel sample, usually 1 g, is put into the oxygen cell of the caloriemeter. This oxygen cell is equipped with an electric device for burning the sample.The cell is placed into an insulated receptacle with a thermometer attached to it. Thus the inside temperature increase can be read during the burning of the sample. The difference in temperature between the indication at the end and at the beginning of the test multiplied by the heat equivalent of the caloriemeter, results in the heat quantity of the fuel measured in kJ/kg. The entire test takes about one hour.

Figure 5: Principal section of a bomb caloriemeter



A makeshift caloriemeter is simple to make. It should be calibrated with a standardized fuel like charcoal, anthracite. For further information consult the author.

5.4 Determination of Gaseous Pollutant Concentrations

Basically there are two simple methods to determine the concentration of gaseous pollutants:

- with the aid of reacting chemicals
- with the aid of catalytical or opto-electronic sensors

Both methods have their pros and cons. Test tubes are chemical sensors, which contain chemical reagents reacting with occurring airborne pollutants. Each pollutant requires a different reagent. The advantage of this method is, that it is quite simple to apply to a variety of pollutants just by using a variation of test tubes with different reagents. The disadvantage is, however, that the tubes can be used only once and in the case of long-term tests cause high costs. If only a a few single measurements are required the low price of 2-3 US $ per tube is of great advantage.

The advantage of electronic sensors is that they can be used for a long time (2000 tests). The purchase, however, is much more expensive. The price of an electronic gas monitoring device comes up to 600 US $ at least. The advantage of its usage lies in real time measurement. A decision for such a device depends on:

- size and number of samples
- variation of maximum and minimum values
- accuracy and precision required

5.4.1 Test Tubes

Presently, test tubes (or also called indicator or absorbtion tubes) are part of the classical monitoring method for gas analysis. The first test tube patent appeared in the year 1917 in the USA. Test tubes are categorized by those with direct readout and sampling tubes whose content will be analyzed in the laboratory. For the simple exposure measurement we will restrict ourselves to the explanation of test tubes with direct readout.

The principle of these test tubes is based on chemical reactions of the test material with the chemicals of the filling section. Since this reaction is connected with a change of colour, the turnover can be read on a scale, as shown in figure 6.

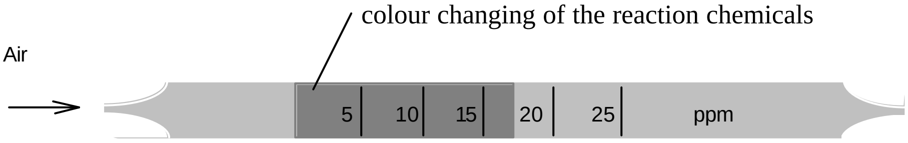


Figure 6: Colour changing in the test tube

The length of the colour section is indicative for the pollutant concentration and can be read instantaneously. The colour change is a related to the mass and the respective volume of air drawn through the tube. There is no need for the user to calibrate the tubes. Most tubes are calibrated to be used with manual pumps for a sampling volume of 100 ml. The sampling volume is given by the number of strokes.

For the application in developing countries, those tubes with multiple range option should be used. Such tubes can be used by simply increasing the number of strokes and thus the volume of air sampled. Before buying tubes the range of concentrations has to be considered. The possible measurement ranges have to be asked from the manufacturer. In table 9 there is are a number of Dräger tubes listed, which can be used for such purpose.

5.4.2 Variations

Basically the tubes are divided into:

- short-term tubes with time spans of 10 seconds up to 15 minutes
- long-term tubes with time spans ranging between 2 and 8 hours
- tubes for active sampling, and
- tubes for passive sampling (diffusion tubes)

5.4.3 Active Sampling

During active sampling process, the air to be tested is drawn through a sampling tube by a pump (see figure 7). Each tube requires a certain number of strokes. The required pump draws exactly 100 cm^3 of air through the test tube. Once the required number of strokes is reached, the measurement should be read and recorded instantaneously. In most cases it will not be possible to secure the readout by storing the tube.

A change of colour indicates the measurement. It is helpful to hold the tube in front of a white background and to compare it with an unopened test tube. Then it will be easy to read the indication directly from the scale. With the pollutant mass m, determined by the analysis, and the volume of air V drawn through the test tube, the concentration c of the pollutant can easily be calculated according to equation 6:

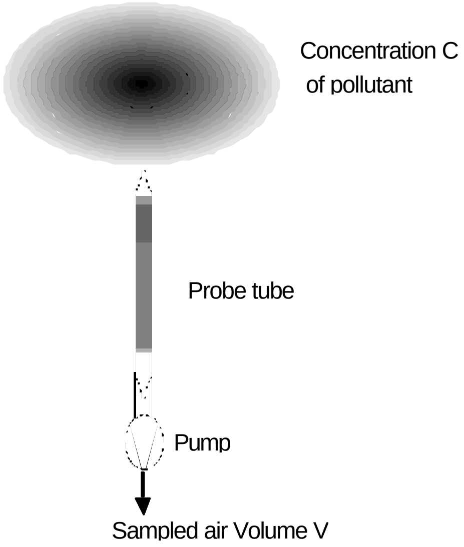
$$\mathbf{c = m/V}$$

Equation 6: concentration of pollutant C

c = the concentration to be measured in mg/m^3
m = pollutant mass in mg
V = volume of air in m^3

As a rule the volume is between 1 and 20 liters. The common sampling volume of manual pumps is 100 ml. The required sampling time should not exceed 3 strokes/min (300ml/min) and pumps should be operated only with minimal force to overcome the flow resistance caused by the tube. Since the volume of air represents the decisive quantity for determining the concentration, great demands are made on the pump and its calibration.

Figure 7: Measuring principle of active sampling



The reading scale usually gives the number of strokes required to read the scala. To achieve more significant readings it is often useful to increase the number of strokes, thus increasing the sampling volume[4].

For example:
A test scale has been calibrated for n=10 strokes. While using the tube with 10 strokes no significant colour change could be obtained. The pumping was continued for another 90 strokes.

The value of colour change has now to be divided by the higher volume, whereas

$$V = n \times 100\ \text{ml}$$

Equation 7: True volume of manually operated sampling

Cr = value in PPM reading of the colour change
C = true value measured
n1= given number of strokes for scale calibration
n2= total number of strokes done

$C = Cr \times n1 / n2$

in our case for Cr =100 ppm, n1 = 10 and n2 =100

$C = 100 \times 10/100 = 10$ ppm

Test tubes for extended volumes generally offer two scales for different times of strokes. For extended strokes generally the scale for the bigger number of strokes will be used for reading[5].

Table 9: Test tubes for extended volume

Pollutant	***reacting chemical***	***Dräger Code***	***measuring range***	***no. of strokes***
CO	I_2O_5	CO 5/c	0,5 - 15 ppm	n = 100
			5 - 150 ppm	n = 10
			100 - 700 ppm	n = 2
CO_2	N_2H_4	CO_2 0,1%	0,1- 1,2 ppm	n = 5

---

[4] There is no absolutely linear correlation between volume and colour change (reaction time plays an important role) for many tubes, the higher accuracy in reading the scale equals out the lower precision caused by the extended reaction time. For example: A reading error in the first third of a CO tube scale may result in a deviation of +/- 30 %, whereas the same reading erreor at the end of the second third of the tube scale results only in a deviation of maximum +/- 10 %. The extension of the number of strokes given by the tube manufacturerer by 10 (10 times the sampling volume/time) results in various deviations for different gases and has to be asked from the manufacturer.

[5] Draeger Tube Handbook. Soil, water and air investigations as well as technical gas analysis. Lübeck, 1994

			0,5 - 6 ppm	n = 1
NO_2	Diphenylbenzidin	NO_2 0,5/c	0,03 - 0,1 ppm	n = 100
			0,05 - 2 ppm	n = 50
			0,5 - 10 ppm	n = 5
			5 - 25 ppm	n = 32
SO_2	IO_3^-	SO_2 0,5/a	0,5 - 5 ppm	n = 20
		(SO_2 is not very suitable for the extension of volume)	1 - 25 ppm	n = 10
HCHO		Formaldehyd 0,2/a	0,04 - 0,5 ppm	n = 100
			0,2 - 2,5 ppm	n = 20
			0,5 - 5 ppm	n = 10
			2 - 25 ppm	n = 3

5.4.4 Passive Sampling

Passive sampling is done with the aid of a so-called diffusion collector.

The tubes or collectors with direct readout are used over a period of 1 to 8 hours for the personal monitoring of average concentrations. They are attached to the clothes and since the sampling is based on a passive monitoring system, no pump is used.

According to the principle of diffusion, pollutant molecules will enter the difussion tubes. By means of a colour-length indicator, the measurement output can be read as the product of concentration and time of exposure (ppm .... etc.). After the measuring is completed, the taken value is converted into an average concentration, according to equation 8:

$$\mathbf{C\ =\ \text{Readout in ppm x h / time in h}}$$

Equation 8: Average concentration in diffusion tubes

5.4.5 Dependency of Test Tubes on Air Pressure, Air Humidity and surrounding Temperature [6]

Test tubes are calibrated by the producer in the laboratory, where the federal registration test takes place as well. Thus all data on the test accuracy of the tubes refer to a temperature of 20°C, a normal pressure of 1 bar and a normal air humidity.

As a rule, air humidity does not affect the conditions for employing the test tubes. Nevertheless, direct contact of the tube surface with liquids (like rain) should be avoided.

The readout on the test tube is directly proportional to the surrounding pressure. This is based on the fact that the air volume is drawn to a normal pressure.
The conversion into the real value of the air pollution is done in agreement with equation 9.

$$\mathbf{\text{concentration} = \text{readout x 1013 bar / actual pressure in bar}}$$

Equation 9: test tube readout dependent on surrounding pressure

An example to this:

Air containing carbon monoxide (CO) is analyzed at a height of 2000 meters. The indication on the test tube amounts to 50 ppm, while the air pressure at a height of 200 m rates 790 mbar (see table 8). According to equation 9 the actual concentration comes up to:

---

[6] from K. Leichnitz, American Industrial etc.

Concentration = 50 ppm x 1013 bar / 790 bar = 64,1 ppm

As far as temperature influence of the test tubes is concerned, it has been proved that, in a range of 0° up to 40°C, the reaction process and the readout are not measurably influenced. Consequently, the tubes should be either cooled down or heated onto a range between 0° and
40°, in case of higher or lower temperatures.

5.4.6 Monitoring by Means of Electronic Monitoring Devices

For measuring carbon monoxide, carbon dioxide, oxygen, nitrogen oxide and sulphur dioxide it is possible to use electronic devices with direct instantaneous readout. The air pollution content is determined by means of sensors. A digital readout indicates the measured value.

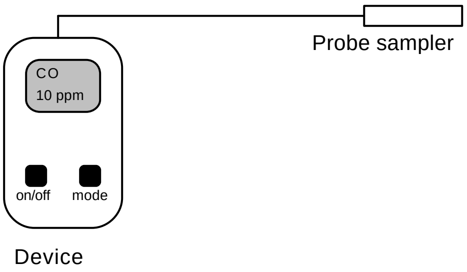


Figure 8: Sensor monitoring device

These devices need to be calibrated before each monitoring session. The calibration occurs by means of a test gas of known pollutant concentration. Due to the sensitivity of the built-in sensors, the devices are particularly suited for low exposure monitoring.

5.5 Determination of Solid Suspended Particulates

Three basic methods are applied in determining solid suspended particulates in the breathing-zone air:

- gravimetric
- chemical and
- optical methods.

According to the gravimetric method, particulate quantities are determined by weight increase. Determination of carbon during combustion is the principle of the chemical method. According to the optical method, determination occurs by means of the degree of reflection of the air or the sample-carrier.

The following paragraphs will discuss only the gravimetric and optical method, since the various other approaches are manifold and not sufficiently suited for non-specialized operators.

5.5.1 Gravimetric Determination of Solid Suspended Particulates

For the gravimetric determination suspended particulates are collected with the aid of a filter after which the weight increase is measured. This can be done by active collection of the test air (with a pump), as well as by passive collection. This last approach is used only for long-term monitoring (weeks, months).

For monitoring exposures of particle pollution of the breathing-zone air during biomass burning, a pump is used to draw in a specified volume of air through a filter. This filter is dessicated for 24 hours and weighed before and after monitoring, thus allowing the determination of particulate pollution in weight per volume. This kind of measurement requires an analytical balance with an accuracy of at least 0,01 mg. Weighing needs to be done instantaneously, because a part of the particulates being of volatile matter.

Concentration of particulates is calculated according the following equation:

$$\mathbf{Ca = (Wff - Wft) \; / \; Q}$$

Equation 10: Concentration of Particulates

Ca = Concentration of particulates in (mg/m^3)
Wff = Weight of test filter after monitoring in mg
Wff = Weight of test filter before monitoring in mg
Q = drawn in volume of air by the pump in m^3/h

5.5.2 Baum/Bacharach Method for Determination of the Soot-Tar Rate

The Bacharach method is a Black Smoke Method in the broadest sense. It allows to estimate quantities of particles and suspended particulates by using the degree of reflection of the sample. Professional devices determine these quantities optically with the aid of highly sophisticated sensor electronics. The Bacharach method uses the naked eye to distinguish rough shades, and is accordingly less accurate.

The Bacharach method was particularly developed for the determination of pollutant emissions from smoke gases of oil combustions. A further development by Dr. Baum can be profitably used for the determination of pollutants from solid fuels. The change of the principle is based on further developing the 10 grey ranges up to 100 ranges going from white to grey and from yellow to red. This allows to determine the yellow and red coloured grey tones of waste gases from solid fuel burning. In addition by solving the samples with acetone, it is possible to detect the particularly health-affecting hydrocarbon derivates, out of the total sample of the collected suspended particulates. Thus a rough differentiation between soot and tar content can be made.

With a manual pump, equipped with absorbant filter paper of a regular degree of reflection (85%), 5750 cm^3 of waste gas per cm^2 of effective filter paper surface is drawn directly into the waste gas channel by several strokes (in most cases 10 strokes, no need for a gas quantity gauge). The soot contained in the waste gas leaves a circular blackish stain of 6 mm diameter on the strip of filter paper. Depending on the tar content in the waste gas there will be a different grey/yellow/brown colouring.

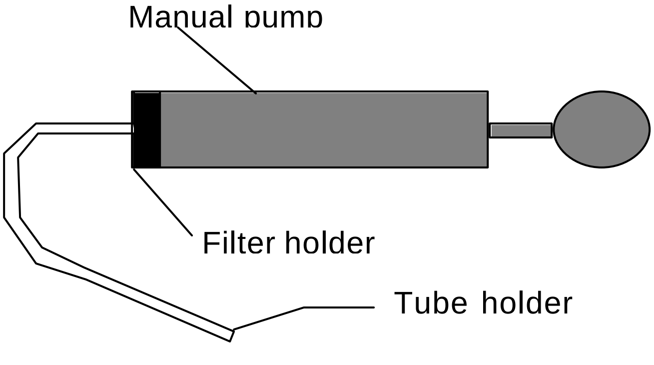


Figure 9: Handpump for determination of soot rate

The air-drawing device shown in figure 9 consists of a handpump with a filter holder and an elastic tube. The connected pump draws the waste gas air through the sample attached in the sample holder.

In the case of constant sample gas volumes, there will be a colouring on each filter surface proportional to the soot and tar content of the waste gas. The colouring of the stains on the filter paper strips will be determined by means of a comparative range (the stains are put under openings in a comparative table, to be found in appendix D). The comparative range is classified into 80 rectangular areas. The numbers underneath the comparative fields indicate the total C concentration in mg/m³.

Combustion with little smoke in the sense of an acceptable health effect, requires that no colouring of the paper appears. The slightest in a range of 10 strokes signifies a serious TSP concentration for those persons staying in this area.

In the absence of colouring, the strokes can be continued. If there is still no clear colouring of the filter paper after 100 strokes, monitoring has to be continued with more accurate equipments measuring a range from 0 to 500 µg/m³. The black smoke or bacharach test applied in the decribed way will only detect TSP concentration clearly above 500 µg/m³.

5.6 Other Instruments to Detect Airborne Pollutants

To analyze more complex mixtures (e.g. suspended particulates of smoke) of airborne gaseous polluntants, there are a number od various other more sofisticated instruments. Those instruments are more versatile on the one hand, but on the other hand they are comparatively expensive and require a specialist to calibrate the devices, interpret the readings correctly and reauire high maintenance costs.

As said before, the prerequisite for measuring gaseous air pollutants is the determination of the concentration with a suitable economical gas measurement device. The more complex subsatnces are, the higher the analytical precision, the more complex the gas measurement technique.

We will only mention here the varies techniques, because anyway this manual is not intended to train specialists. The most commonly used instruments, depending on method, operational principals and task, are:

- flame or photo ionization detectors
- gas chromatogaraphers
- infrared spectrometers
- UV-VIS photometers
- laboratory analysis with gas wash bottles (Impinger)
- Sophisticated substance selective instruments e.g. with electrochemical sensors

The choice of monitor or method depends upon the objective. Each of the devices and methods have their limitations and advantages. There is no universal monitor for all possible scenarios.

Photo and flame ionization detectors are distinguished by short response periods but the do not offer substance selectivity. Gas chromatographers, infrared and UV-VIS photometers require specialist handling during calibration and reading. Electrochemical devices are generally not designed to measure lower concentrations and are difficult to use under some field conditions (in conjunction with high particulate concentrations).

Probes of complex mixtures can also later on be brought for laboratory analysis. For few measurements this is always more economic then the purchase of expensive equipment with a higher analytical read out. Laboratory analysis are usually carried out with the help of gas chromatography and or in combination with mass spectroscopy.

The monitoring of suspended particulates provides little information on the composition of these materials. Gaschromatography allows the determination of the various hydrocarbon compounds.

Nowadays all modern gas chromatographers are equipped with serial computer ports. Software allows analyzing the peaks, so that precise information can be given on type and quantitiy of the material.

5.7 Comparing the Costs of the Various Monitoring Methods

Table 10 compiles and compares once more the costs from chapters 5.1 to 5.6.

Method	Total of fixed costs	Total of variable costs
Weighing	Purchase of scales US $ 150 - 170.-	
Temperature measurement	Purchase of a thermometer US $ 30 - 360.-	
Humidity	Purchase of a hygrometer US $ 300 - 950.-	
Heating value	Purchase of a caloriemeter and a Pelletier press US $ 6000 - 8000.-	
Waste gas analysers, electronic for CO, CO_2, NO_2, O_2	Purchase of a handheld digital instrument for 1000 US $	Gas for calibrating Batteries 25 $/y
Gravimetric determination of particulates	Purchase of a analytical balance, US $ 4000.-, a pump, filter and filter unit US $ 1000.-	Batteries for the pump (25$), filtermedia
Soot-Tar Rate	Purchase of a pump US $ 160.-	Filter strips, package per 100 = US $ 5,10
Test tubes	Purchase of a pump US $ 160..-	Test tubes for about 2-3 Us $ / piece
Gas chromatographer	Purchase of a gaschromatographer US $ 25.000.-	Gas for calibrating

Table 10: Costs of monitoring methods

Comparison of the costs shows that accuracy and precision has its price. Such a high degree of accuracy, however, is not required in 90 % of all cases of biofuel monitoring. It is important to determine how significantly pollutants diverge from the permitted limits, and for this purpose, simple monitoring methods will do sufficiently.

The use of electronic instruments in developing countries presents many disadvantages and possible sources of mistakes due to great demands on personnel and working conditions. In using calibrating devices or analyst balances, for instance, readout or adjustment are very often not accurate. The extreme working conditions to which electronic and precision engineering devices are exposed to in developing countries lead to mechanical, thermal and sensorial problems and to completely wrong indications, which might be documented by unexperienced personnel. In those locations where air pollution is highest due to biofuel burning, there is often no electricity to operate electronic devices or battery chargers.

There is generally no service option for sensitive electronic instruments in most developing countries. Many of these devices operate incorrectly under the climatical stress found in tropical countries. Field workers have limited capabilities to operate instruments, thus limiting the options for multiple application of sensitive precious instruments.

6.0 Practical Guidance on Conducting Simple Exposure Measurements

The following practical monitoring can serve as a model for a simple exposure measurement, for instance to execute national standards and norms. A successful measurement consists of the determination of surrounding conditions and of air pollutants and the data evaluation.

Monitoring is conducted under characteristic working conditions, which means that a sample survey is carried out among the target group. First of all basic conditions have to be considered and documented, before starting the various monitoring processes.

This chapter explains the manifold underlying considerations while planning various simple monitoring surveys. Practical checklists for the described measurements can be found in the annex A. Statistical methods of survey planning are excluded in this manual for the sake of brevity and because there are already many publications on survey planning and evaluation available, which can easily be adapted and utilized for the mentioned tests.

It is advised, to carry out earlier described emission and consumption tests (chapter 4.1)besides or simultaneously with the proposed exposure tests in order to get a technical evaluation of tested devices. Only then a clear understanding of the reasons for high exposure rates can be reasonably evaluated.

6.1 Test Preparation and Determination of Frame Conditions

Surrounding conditions are to be determined and documented in the test area, which, as a rule, will be the kitchen[7]:

- geographic location, name of the village, the family, the cook and the tester
- Type of fuel used during monitoring
- Type and function of the cooking stove used
- Quantity and type of prepared meals
- Seasonal peculiarities
- Moment of sampling
- Cooking stoves / description of the kitchen
  in case of open fireplaces:
    1. climatic and wind conditions
    2. surrounding temperature
    3. air humidity
    4. description of working environment and process of work

in closed kitchens:

1. Size of the area in m³ - Sketch of the area including the location of the stove
2. area temperature
3. air humidity
4. description of working environment and process of work

- Location of sampling:

  Sampling is normally done at breathing-zone level of the cook by means.

An average measurement of a working environment requires an accurate documentation of the various monitoring cycles. The following diagram illustrates a typical measurement development in a rural kitchen:

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[7] See also sample record in the annex

The diagram represents a real-time measurement of CO in a kitchen with dung- and wood-firing while preparing an ethopian national food (injera). The model shows the extremely different concentrations which can be measured during a cooking-process. The continued line illustrates the measurement with dung-firing and the dotted line the one with wood-firing. Although dung-firing represents a really extreme case, the line shows how difficult it is sometimes, to determine accurate average concentrations with timewise discontinuous measurements.

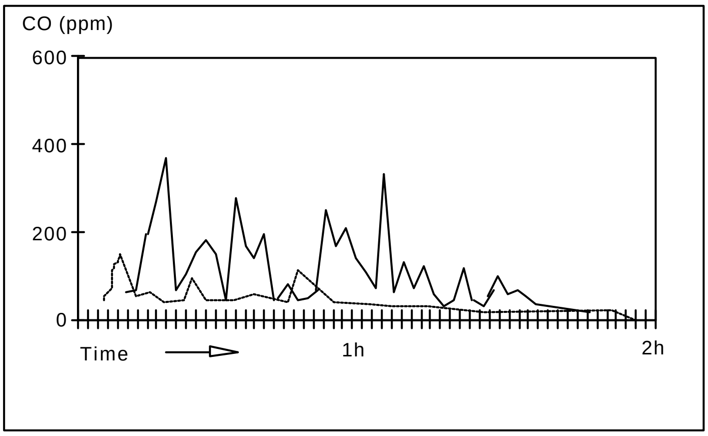

Figure 10: Real time diagramm of CO for wood and dung

Maximum concentrations always occur when new fuel is put onto the embers. In practice there are two possibilities to record the trend of this variation without a real-time measuring device.
The first one is a permanent discontinuous measurement in fixed time units (e.g. 1 stroke/min.), the second possibility is to registrate the cooking phases timewise and to categorize them by concentration, e.g. in the heating-up -, the simmering- or the post-cooking phase. For long-term monitoring with high concentrations, therefore, diffusion tubes should be used for gas monitoring.

Two values are of importance for assessment of health-affecting pollutions:

- the average pollution in the working environment, and
- the maximum pollution in the working environment.

At this point we would like to remind the reader once more that these monitoring methods are not meant to be on a scientific level and are only used for a rough estimation of the pollutant potential.

Measured values are registered in a test protocol. Such a protocol is to be found in appendix B.

6.2 Calibration methods

Calibration of instruments is used to gauge and standardize instruments, so that measuring results can be compared and to eliminate or minimize the influence of the instrument on the measuring result. It can be applied to any chemical, electronical or physical process in the monitoring process.

In our case, for the maintenance of an instrument´s precision and accuracy, there are basically two needs for calibration. The calibration of gas sensors in electronic devices and the volume flow of pumps. Chemical indications of tubes for example are precalibrated (by mixture) and standardized and require therefore no additional calibration. The calibration of visual indications of sampled probes (e.g. particle filters) can also be applied, but is generally done in the frame of a research project and not in the frame of day by day instrument maintenance.

6.2.1 Calibration of electronic gas detectors.

Electronic equipment for gas detection is generally calibrated with the help of a so-called span gas. A span gas will force the sensor always in a standard indication and reset the digitalized indication. Type and procedure of the calibration depends on the device and can be be found in the detector´s documents.

6.2.2 Calibration of air pumps

Manually operated pumps

Manually calibrated pumps have to be calibrated to monitor the sampled volume per stroke. Most offered manual pumps have a corresponding volume according to the sampling tubes or filters used with the pump (usaully 100 ml or 163 ml). But in general any type of manual vacuum pump can be used for air sampling (even converted bicycle pumps), it is only important to observe the flow resistance of sampling tubes or filters[8]. It is important to convert the number of sampled strokes and pump volume to the required sampling volume and time.

For the calibration one needs a burette of little more volume than the pump. The burette can also be replaced by cheaper plastic measuring cylinders, which are cut flat at the end. With the help of a second burette it can be calibrated vice versa, from top to bottom. At first a hole is drilled in the bottom, where a tube connection can be fit. The tube is then fit onto a washing bottle and the outlet goes onto the sampling tube or filter of the manual pump. With the help of a soap solution, bubbles are soaked into the buret up to the pump´s fully developed capacity. Please observe the required time span of maximum 3 strokes/min for a 100 ml pump.

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[8] For example: in a case of emergency the author was converting a chinese bicycle pump into a sampling pump. In later calibration tests it showed higher precision and a lower deviation in sampling volume, than the „authorized“ standard instrument of a German sampling instrument manufacturer. The effectiveness and precision of manual pumps is determined by the limitation and guiding of the rod, which pulls out the cylinder, and it depends also on the quality of the grease used to seal cylinder and piston (silicon grease is best to use).

The value of the sampled volume is noted, and the pump is operated again, picking up the next soap bubble. This procedure is repeated for at least six times. Depending on the deviation, the tests are repeated more often. For example for a simple average deviation of more then +/- 2 % another 4 times. For a deviation of +/- 4% another six times and so on. If pumps have a big deviation of around 10 % or so, something is wrong either with the greasing or mechanic qualities of rod guidance or stove or cylinder construction. Those pumps should be replaced.

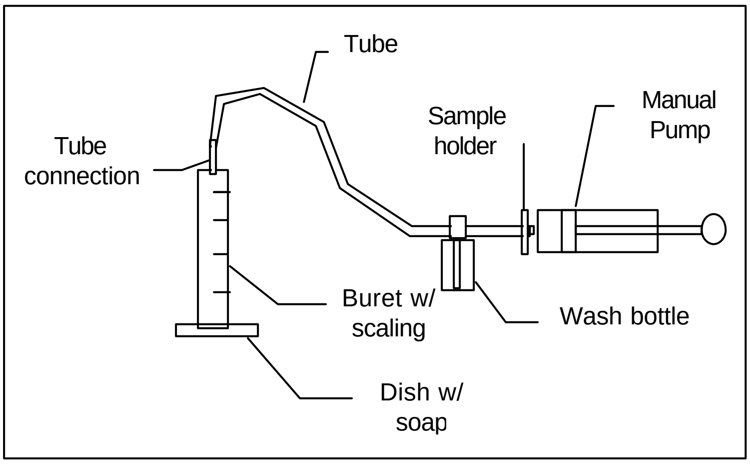


Figure 11: Manual pump calibration

Calibration of elctronic pumps

Similar to the above described calibration for manual pumps, the calibration of the volume flow of electronic pumps is done with the help of a burette

The time is taken, while the soap bubble passes at a certain mark until it reaches a second mark. The volume passed during this time can be either calculated ($V= l * \Pi r^2$) or the difference between the two readings is taken (t1-t2). From the time and the volume, the volume flow can be calculated and is usually expressed in l/min or ml/sec.

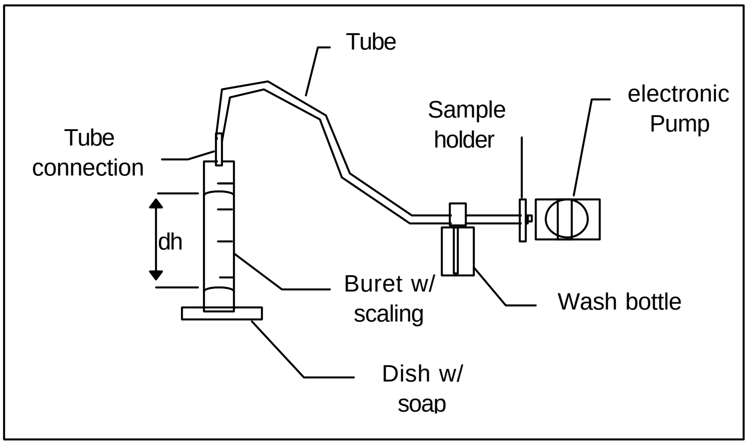


Figure 12: Calibration of electronic pumps

Each type of calibration needs practice and a bit of experience. There are also more sophisticated instruments like a spirometer, venturi meter, rotameter, mercury sealed piston and many others, which need generally more training and experience to use and calibrate, than the described method.

6.2.3 Calibrating Visual Evaluation Scales for Gray Shade Tests

Grey shade scales can be developed by yourself for your own application, range and fuel. For this purpose you need to conduct a series of TSP tests with the help of a electronic device and a gravimetric analysis. After you have collected a whole series of different shades, preferably starting from very low concentrations, you will go on sampling for a range of clearly different shadings (e.g. 10 different shadings). After the gravimetric analysis you can put a scale to each shade and the color is put on a scale. Now the verification of the scale needs to be done. You will again collect filter samples corresponding to your set scale. Again these filters have to be analysed gravimetrically. Now you can compare the results again and see how much deviation you will find. Usually this type of confirmation should be done at least 4 times. If there is still a great variation in results, you need to do even more tests until you will find statistically acceptable results. However, this job is a research job and needs at least two to four weeks for realization. It is therefore only recommended for national research institutions, which have the equipment, the personnel and the funds to do so. Nevertheless it can help to verify and specify the black smoke test, which can be used widely for simple testing.

6.3 Determination of Air Pollutants with the Aid of the Modified Bacharach Pump

First of all the elastic test tube is attached with a pin at breathing level (mouth, nose), e.g. to shirt collar, kerchief, hair pin. Important is that the level and position are as realistic as possible in terms of the breathing position.

6.3.1 Monitoring Average Pollution in the Working Environment

Gas- and Particulate Monitoring

Monitoring should start at the beginning of the cooking activities. Gas monitoring usually takes 3 strokes of a 100 ml/minute and it is possible to conduct particulate monitoring at the same time.

If there are enough tubes at disposal, measurements can be repeated immediately. If not, monitoring time should be adapted to the number of measurements and their purposes. The number of strokes e.g. can be reduced to 1 pump/minute, which means that only after ten minutes there will be a need for a new tube.

The number of measurement series has to be increased depending on the variation of maximum and minium values. Especially in case of very low concentrations several measurements will be necessary, the significant excess of limits being accordingly low. Measurements with high maximum and minimum values, on the contrary, do not require many measurements, the significance and danger of the concentration being apparent, especially when the minimum value indicates twice the value of the permitted standard for working environments (for CO e.g. 60 ppm).

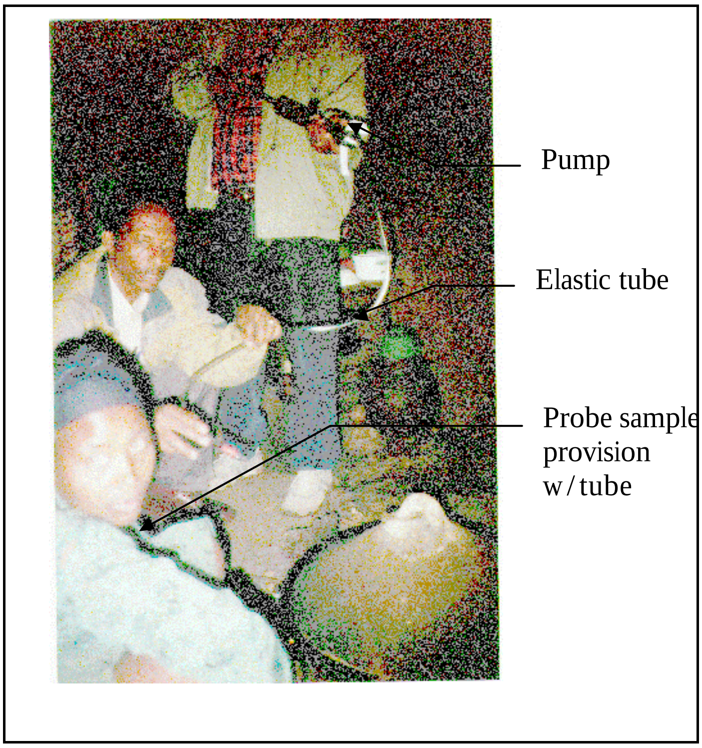


Figure 13: Taking samples with a manually operated pump

In case of the TSP monitoring with the bacharach pump, many measurements can be conducted one after the other, thanks to the cheap filters. First of all a zero measurement is done before starting the fire to ensure that no other particulates pollute the air. After that the firing measurements are done in appropriate time lapses (depending on height and variation of the pollution).Towards the end of the monitoring phase measurements are continued until there will be no identifiable staining left on the filter paper. Important here is to register the time.

If no staining at all will show during all these measurements an extended test will be conducted. For this purpose the test with the same filter paper is repeated 10 times. If there is still no identifiable staining, the occurring suspended particulates at least do not present a high excess of the limits.

In the case of staining during permanent measurement, the monitoring should be repeated a few times in order to determine a meaningful average value. To this end the values of the comparison scale are added up and divided by the number of measurements.

For example:
The test resulted in the following values: 0,0,8,8,0,0; the total of number of measurements is 16.
This sum of the values (16) is then divided by the number of measurements (6). Accordingly the average value is around 2,7.

The following diagram illustrates the comparison between typical courses of a real time- and a discontinuous particulate measurement.

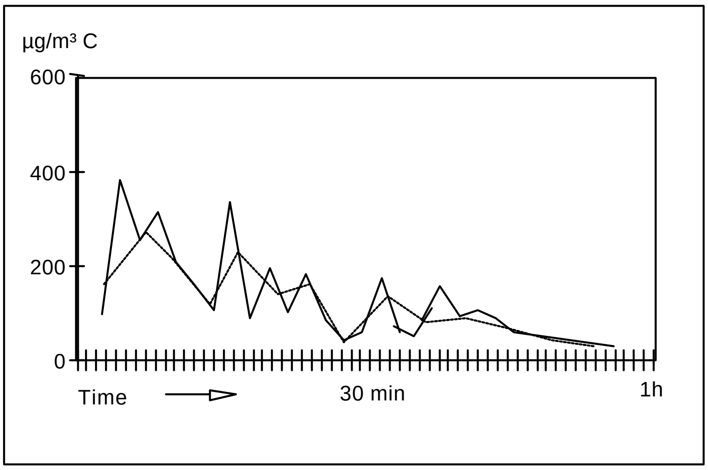
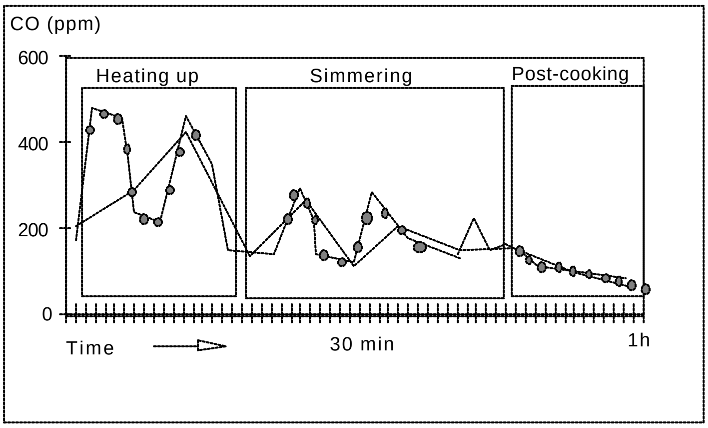


Figure 14: Comparison of a real time and discontinuus particulate measurements

_______ = Real time course
----------= discontinuous monitoring
every 4 minutes

The CO measurement can be conducted in a similar way or simultaneously. However, it is also possible to categorize the measurement by specified cooking-phases:

Figure 15: CO test series stratified according to cooking phases



______	Real time course
--------	Ongoing discontinuous measurement (every 4 minutes)
ooo	Sequential measurement (1 measurement per cooking-phase; each 10 strokes at 1 pump/minute)

Time is registered for the single cooking-phases, the average value of he sequential measurement is divided by time to determine an average pollution for the total cooking-time.

Average concentration during total cooking-time. = $((ø1 \times \Delta t1) + (ø2 \times \Delta t2) + (ø3 \times \Delta t3)) / To$

øn	Sequential mean
Δtn	Duration of single cooking-phases in minutes
To	Total duration of cooking-time

6.3.2 Monitoring Maximum Concentration

Gas Monitoring

Without a real time measuring device it will not be possible to conduct an accurate measurement of maximum concentrations. Though, with some experience and the aid of the correct test tubes, it will be possible to determine maximum concentrations. While selecting the test tubes it is important to choose those tubes that need only one pump for the expected concentration. Maximum concentration levels typically occur during high burning phases, e.g. in the heating up- phase. At the moment when smoke development increases in an unbearable way a relatively reliable approximate measurement can be done of maximum concentration. If it is not possible to determine a strong variation of smoke pollution during the various cooking-phases, the measurement of maximum concentration is of minor importance, being only insignificantly above the average pollution. The importance of maximum measurement for health effects is given especially, when maximum concentration exceeds a factor of 10 to 20 above average concentration.

Particulate Monitoring

Here again it is possible to determine by means of the 1-pump measurement whether there is a significantly high divergence between average and maximum pollution. If, for instance, already after one pump in the heating-up phase there is a perceptible stain on the filter, comparable e.g. to the average colouring of the value, a high variation can be proved and regarded as indication.

6.3.3 Monitoring with Diffusion Collectors

Diffusion collectors are passive samplers which work without using a pump. They change colour through the time-related contamination with the surrounding polluted air. The big advantage of diffusion collectors is that they are very inconspicuous and may be worn over long periods (1,5 to 8 hours depending on the concentration). For short-term monitoring (0,5 -1,5 h), however, the collectors can be used only in the case of extremely high concentration. Although diffusion collectors are not very accurate (+ /- 30%), they are a very helpful and a low-priced device for checking quantities, especially when low variations of working environment concentration can be expected.

Like the test tubes, the diffusion tubes are possibly attached at mouth- or nose level. Afterwards the measuring value is read and divided by the duration of measurement, resulting in an average quantity of x ppm/h.

Sedimentation samplers for dust monitoring

Collecting dust over longer periods in so-called sedimentation samplers is an inexpensive but efficient sampling method for TSP. It is especially beneficial for comparison. The samplers are simple glass containers, which have to be placed in the kitchen in such way that they are suited to collect average dust settlements, e.g. centrally under the roof. Sedimentation sampling does not provide specific exposure data but it gives interesting additional information on the overall particle situation. It is a long term passive area monitoring technique and the sediment can be analyzed by weight or with the help of a gaschromatographer.

6.4 Interpretation of Measuring Results

Two quantities are important for evaluation
- the level and
- the duration of exposure.

Relatively low but permanent exposures can have the same detrimental effect as high short-term ones. Limits, therefore, are only valid for certain durations of exposure [9] as provided in Table 3 in Chapter 2

Category	Short-time value in times legal standards	Exposure time in minutes	Occurence per working time
Locally irritating substance	2	5	8
Irritant reabsorbing substance; effective within 2 hours	2	30	4
Irritant reabsorbing substance; effective after 2 hours	5 - 10	30	2
Less effective substances	2	60	3
Strong smelling substances	2	10	4

---

[9] The evaluation of maximum concentrations however is difficult, because the normal working place standards cannot be used to value short time exposures. In the evaluation of maximum short term concentrations pollutants are usually divided into five categories as shown in Table 16. There are number of example how short term concentrations can be extrapolated

It is important to relate the test results to cooking time, changing ventilation conditions, seasonal changes of working places and fuels. Only in the scope of the criterias listed under chapter 6.1 the entire impact of measured exposures can be understood.

If the concentration levels found are considerably high, it is useful to relate the results to related diseases and complains detected either through direct interview, or through official health records.

During the evaluation it is important to monitor the variation of results. Those variations need to be followed up by scanning the documented test conditions. After the test data is preliminarily verified it can be computed and be put in a database. The data base should preferably contain notes about special events, which occured during probe sampling.

If relevant, the data can be further processed for statistical proof. Methods for statistical interpretation and calculation can be found in many guides for monitoring and evaluation published various development organizations. We recommend: „Health and Community Surveys“, Volume I and II, published by IEA and WHO, last edition 1992, which can be acquired through all WHO country offices around the world.

6.4.1 Calculation of Indoor Air Concentrations

This chapter will show the most important equations for calculating various dimensions of indoor air pollution. The values registered in the monitoring report allow calculations of indoor airpolution, the intensity of the source of this kind of pollution, the reactions rate and the air exchange rate.

Concentration of indoor air pollution

The concentration of indoor air pollution can be calculated with the aid of the following formula, which defines a weighing of mass. This equation can be applied, for example, when indoor air pollution concentrations are impossible to measure directly but source strength and the ventilation conditions (air exchange rate) are known.

$$\mathbf{C = ((P \times a \times Co) + S/V) \ / \ (a+k)}$$

Equation 11: Concentration of indoor air pollution, calculated from emission measurement 8)

C = Concentration of indoor air pollution in ppm
P = Fraction of the surrounding air pollution (without dimension), generally determined = 0,7
a = Air exchange rate (h-1)
Co = Concentration of surrounding air pollution in ppm
S = Intensity of the source of indoor air pollution (cm^3/h)
V = Area volume (m^3)
k = Reactions rate (h-1)

This equation illustrates the pollution of the indoor air, developed from the outside or respectively existing air pollution in addition to the pollutants caused by the cooking stove.

The intensity of the source of indoor air pollution is calculated by:

$$\mathbf{S = Q \times E \times F}$$

Equation 12: Intensity of the source of indoor air pollution

S = Source strength in µg/h
Q = Power rate of the stove (kJ/h)
E = Pollution rate of the stove (ug/kJ or cm^3/kJ)
F = Ventilating factor at the stove (without dimension, 0 to 1:
0 corresponds to no ventilation, 1 corresponds to complete ventilation)

The emission measured at the stove enters into this equation. Further factors are the duration of the use of the stove in kJ per hour and the area ventilation - the last value being estimable.

Reactions rate:

$$k = a \times (Co - C) / C$$

Equation 13: Reactions rate

C = Concentration of indoor air pollution in ppm
a = Air exchange rate (h-1)
Co = Concentration of surrounding air pollution in ppm

This equation illustrates the extent of air pollution being neutralized through reaction.

Air exchange rate:

The air exchange rate expresses the decrease of air pollution. It can be simply done by starting a fire with a significant CO concentration in the room. By then the pollutant source (the fire) has to be removed or extinguished completely. The following decay of the concentration provides the basis for calculating the number of times of complete air exchanges in the room. For village hut situations it can be simplified by the following equation:

$$a = (\ln C0 - \ln Ct) / t$$

Equation 14: Air exchange rate

a = the air exchange rate per hour
lnC0 = the logarithm to basis 10 of the pollution measured at the beginning of the decay (after removal of the pollutant from the room)
lnCt = the logarithm to basis 10 of the pollution measured after the time t
t = Duration of test

ANNEXES

A. Checklists for Preparation, Calibration, Monitoring and Evaluation

Diffusion Tubes

Materials needed:

- Tubes for relevant pollutant
- Tubeholder
- Protocol
- Container for glass disposal

Application:

Personal monitoring
Short term 0,5 to 2 hours with very high average concentraions of more than 60 ppm
Long term 2 to 4 hours with concentrations of more than 30 ppm
Long term 2 to 8 hours and more with concentrations of more than 10 ppm

Reading:

in ppm x h or sometimes mg/m³

Calibration:

no calibration needed

Documentation:

Tube type, Starting Time, Ending Time, indicated value

Calculations needed:

Cr = Indicated value
ht = Duration of sample taken in hours (e.g. 3hours 15 min will be 3,25 hours)
C = True value

$$\mathbf{C = Cr / ht}$$

Example:
Cr= 210 ppm h
ht = 3.25 h

$$C = 210 / 3.25 = 64.6 \text{ ppm}$$

Procedure:

1. Break of tip (red mark) on one side of the tube with the help of the Filterholder.
2. Deposit glass waste in special glass container
3. Clip Filterholder near breathing zone to shirt or hair spung.
4. Register time sampling starts
5. Take of tube from the filterholder at the end of sampling time.
6. Read the indicated value in front of a white surface, or with the help of a flashlight.
7. Eventually close tube tightly and deposit savely.

Accuracy:

As claimed by the manufacturer, e.g. for CO +/- 30 %

Short term indicator tubes (also absorbtion or Dräger tubes)

Materials needed:

- Tubes for relevant pollutant and relevant concentration
- Tube opener
- Sampling pump (in case of a piston pump also filterpaper)
- Tubing
- Clip or sample holder
- Flashlight
- Protocol
- Container for glass disposal

Application:
Personal monitoring, area monitoring
Short term up to 15 min

Reading:
directly in ppm or sometimes mg/m³

Calibration:
Sampling volume of 100 ml

Documentation:
Tube type, Starting Time, Ending Time, instantly indicated value, no. of strokes, fuel used, activity, phase

Calculations needed:
for all calculations
Cr = Indicated value
C = True value

Conversion to atmospheric conditions (F-factor):

F = Factor for true atmospheric conditions
F = 1013 / actual atmospheric pressure at sampling site

Example:
Sampling site is at 2000 m altitude, the atmospheric pressure is 790 mbar (tubes are normed at 1013 mbar)
F = 1013 / 790 = 1.28
For Cr = 30 ppm, C has to be calculated **C = 30 x 1.28 = 38.5 ppm**

Correction of indicated value by true sample volume (stroke factor):

S = Factor for true sample volume
Ng = given strokes for the indicator scale
Nt = total number of strokes

S = Ng / Nt

Example:
Ng = 10
Nt = 20 S = 10 / 20 = 0.5
For Cr = 30 ppm, C has to be calculated
C = 30 x 0.5 = 15 ppm

Correction of indicated value by true pump volume (pump factor):

P = Factor for true pump volume
Vc = average true calibrated volume
Vr = required volume

P = Vr / Vc

Example:
Vc = 101.5
Nr = 100

P = 100 / 101.5 = 0.985

For Cr = 30 ppm, C has to be calculated

C = 30 x 0.985 = 29.6 ppm

Conversion of ppm to mg/m³ and vice versa

Gas	Mass of mol (g/mol)	Factor to convert ppm into mg/m³	Factor to convert mg/m³ into ppm
Carbon monoxide CO	28	1.16	0.86
Nitrogen dioxide NO_2	46	1.91	0.52
Sulphur dioxide SO_2	64	2.66	0.37
Formaldehyde HCHO	30	1.25	0.8
Benzol C_6H_6	78	3.25	0.31

As an example:
1) A carbon monoxide content of 10 mg/m³ was measured. This value corresponds to 0,86 x 10 mg/m³ = 8,6 ppm
2) The measured value of formaldehyde 0,3 ppm corresponds to 1,25 x 0,3 ppm= 0,375 mg/m³.

Procedure:

1. Break off both tips of the tube with the help of the tube opener.
2. Deposit glass waste in special glass container
3. Point arrow towards the sampling pump
4. Insert tube tightly into the tubing/tube holder
5. In case of a piston pump use a dummy filter and chain calibration
3. Clip tube holder near breathing zone to shirt or hair band.
6. Register time sampling starts
7. Start with smallest measuring range
8. Suck air through the tube and note total number of strokes
9. Note the end of sampling
10.Take of tube from the tube holder
11. Read the indicated value in front of a white surface, or with the help of a flashlight.
12. Note indicated value
13. Eventually close tube tightly and deposit safely.
For evaluation:
14. Multiply indicated value with the F factor
15. In case given strokes have been exceeded, multilply with the S factor
16. Multiply with the P factor

Accuracy:

For given strokes and given scale as claimed from the manufacturer, e.g. for CO +/- 10 % .
For additional strokes and higher volume sampling add +/- 5 % to the given accuracy.

Grey Shade test (also Black Smoke Test)

Materials needed:

- Filterpaper
- Sampling pump
- Tubing
- Clip for tubing
- Protocol
- Grey shade scale
- Acetone

Application:
Personal monitoring, area monitoring, emission test
Generally for excess TSP concentrations
Short term for very high concentrations at least > 10 mg/m³
Long term for moderately high concentrations in the range of minimum 0,5 to 19 mg/m³

Reading:
reflection grade with the help of a grey shade scale

Calibration:
Sampling volume of 163 ml

Documentation:
Tube type, starting time, ending time, grey shade, no. of strokes, fuel used, activity, phase, appearance of hydrocarbon derivates
To note on filter paper: Date, Test no. Family or Cooks name, No. of strokes

Calculations needed:
for all calculations
Cr = Indicated value
C = True value

Grey shade and approximate concentration
For grey shade 0-9 (white = 85 % reflection grade, each shade grade represents 10 % less)

Shade no	mg/m³
0	0
1	7
2	14
3	22
4	36
5	54
6	90
7	125
8	173
9	260

Conversion to atmospheric conditions (F-factor):

F = Factor for true atmospheric conditions
F = 990 / actual atmospheric pressure at sampling site

Example:

Sampling site is at 2000 m altitude, the atmospheric pressure is 790 mbar (Note the pump is normed at 990 mbar.

$$F = 990 / 790 = 1.28$$

For Cr = 7 mg/m³, C has to be calculated

$$\mathbf{C = 7 \times 1.28 = 8.96\ mg/m^3}$$

Correction of indicated value by true sample volume (stroke factor):

S = Factor for true sample volume
Ng = 10 (given strokes for grey shade scale)
Nt = total number of strokes

$S = Ng / Nt$

Example:
Ng = 10
Nt = 20

$$S = 10 / 20 = 0.5$$

For Cr = 30 ppm, C has to be calculated

$$\mathbf{C = 30 \times 0.5 = 15\ ppm}$$

Correction of indicated value by true pump volume (pump factor):

P = Factor for true pump volume
Vc = average true calibrated volume
Vr = required volume

$P = Vr / Vc$

Example:
Vc = 163.5
Nr = 163

$$P = 163 / 163.5 = 0.996$$

For Cr = 7 mg/**m³**, C has to be calculated

$$\mathbf{C = 7 \times 0.996 = 6.97\ mg/m^3}$$

Procedure:

1. Insert filter tightly into the filterholder in the pump
2. Clip tube holder near breathing zone to shirt or hair spung.
3. Register time sampling starts
4. Start with smallest measuring range
5. Suck air through the tube and note total number of strokes
6. Note the end of sampling
7. Take filter off the filter holder
8. Read the indicated shade value with the help of the scale
9. Note indicated value
10. Store filtersample in a dust free container

For evaluation:

11. Multiply indicated value with the F factor
12. In case given strokes have been exceeded, multilply with the S factor
13. Multiply with the P factor

Accuracy:

For given strokes and given scale (for calibrated fuels) as claimed from the manufacturer, +/- 30 %

Gravimetric Evaluation of Particulate Sampling

Materials needed:

- Filters (0.5 to 4 µm pore size)
- Sampling pump (electronic or manual)
- Tubing
- Clip for tubing
- Protocol
- Tweezers
- Analytical Balance (Accuracy 0.00001 g and smaller)

Application:
Personal monitoring, area monitoring,
Short term for concentrations above 10 mg/m^3. Long term for any detectable concentration.
Quantitativ analysis of particulates. Option to do additionaal chemical analysis of sampled TSP.

Reading:
by determining weight of sampled matter on the filter

Calibration:
Daily calibration of the flow rate of the pump, including tubing and filter
Common flow rates range from 1-5 l/min

Documentation:
Tube type, starting time, ending time, initial weight of filter, weight of filter after sampling, fuel used, activity, phase, appearance of hydrocarbon derivates
To note on filter box: Date, Test no., Filter No., Family or Cooks name, Time

Calculations needed:

Vt = Total volume sampled in m^3
v = Flow rate in l/min
Tt = Total sampling time

for electronic pump devices:

$$Vt = Tt \times v$$

Example:
Tt = 60 min
v = 2 l/min Vt = 60 x 2 = 120 l

for manual pumps:
Vp = Volume of manual pump
Nt = Number of strokes

$$Vt = Vp \times Nt$$

Example:
Vp = 0,163 l
Nt = 10 Vt = 0.163 x 10 = 1.63 l

<u>Concentration of TSP</u>

Wi = Initial weight of filter
Wf = Final weight of filter
dW = Total mount of sampled TSP
C = Concentration of TSP in mg/m^3

$$C = dW / Vt$$

where

$$dW = Wf - Wi$$

Procedure:

1. Dessicate filters in dessicator for 24 hours
2. Measure initial weight with analytical balance (at least 5 times), using tweezers for filter moving and a dust free working environment (clean balance with spirit beforehand)
3. Store filter in filterbox and label with initial weight and filter number
4. Calibrate pump before each test
5. Charge a number of batteries according to pump and sampling time requirement
6. Assemble filter and filterholder with the help of tweezers
7. Clip filter holder near breathing zone
8. Note starting time
9. Note important activities
10. Note ending time
11. Remove filter holder and take filter out with the help of tweezers
12. Place filter in the filter box and note : Date, Test No., Cooks / Family name, (event. Tester initial)
13. Put filter in dessicator for 24 hours before weighing
14. Clean analytical balance with spirit
15. Weigh filter sample with analytical balance, at least 5 times)
16. Store filter in filter box for future reference or further chemical analysis

For Evaluation

17. Calculate total volume sampled in **m^3**
18. Multiply indicated value with the F factor when sampling site was at different altitude than calibration (atmospheric pressure at calibration site / atmospheric pressure at sampling site)
19. Divide TSP in mg by the total volume sampled in **m^3**

Accuracy:

Depends on the accuracy of the pump and the analytical balance (claims of manufacturer)

Electronic gas sampler

Materials needed:

- Electronic gas sampler
- Tubing
- protocol

Material list is only valid for electronic devices, which can be calibrated with ambient air, no instruments for use with span gas are adviced here, because span gas acquisition and transport is generally a problem in developing countries.

Application:

Personal monitoring, area monitoring
Short and long term
Use with data logger to be used with computer, specifically good for air exchange measurements

Reading:

directly in ppm or sometimes mg/$\mathbf{m^3}$

Calibration:

description here is only for devices, which automatically calibrate itself with ambient air

Documentation:

Starting Time, Ending Time, Concentrations are noted every x minutes depending on monitoring length (e.g. 1 min for 30 min monitoring time) fuel used, activity, phase

Calculations needed:

Mean average
and
Time weighted average

Procedure:

1. Fix instrument or tube extension directly at cooking person as close as possible to the breathing zone
2. Note starting time
3. Note concentrations according to a fixed frequency
4. Note end of measuring

Accuracy :

As given by manufacturer, usually +/- 1 ppm or mg/m^3

B. Fieldtest Protocols

Air exchange measurement in Tigrai / Training 1994 Date:

village name :..

family name :..

cooks name :..

Remark	Time	PPM CO	Remark	Time	PPM CO

Injera Fuelconsumption Fieldtest Data Sheet in Tigrai 1994

Serial No.		Date:	
Village		Surveyer	
Family		Cooks name	

No. Fuelload	Weight w/jar	- Weight jar	Net Weight	MJ/kg	Total MJ	Calc. Values
DUNG						
1.						
2.						
3.						
4.						
5.						
TOTAL			*		+	
STRAW						
1.						
2.						
3.						
TOTAL			*		+	
WOOD						
1.						
2.						
3.						
TOTAL			*		+	
TOTAL MJ					F=	MJ
INJERA LIQ.	Weight w/jar	- Weight jar	Net Weight		Totals	
1.						
2.						
3.						
TOTAL					+ I=	kg
INJ. BAKED	Wgt. w/bas	- Wgt basket	Net Weight			
1.						
2.						
TOTAL					-	
WATEREVAP.					W=	kg

Ambient temperature	Injera liqid temprature T1	Ambient humidity	Humidty Dung	Humidity Straw	Humidity Wood
° C	° C	%	%	%	%

<u>Calculations</u>:
F = Energy input in MJ
I = Weight of Injera liquid in kg
W = Weight of evaporated Water in kg
μ = System efficiency in %
specific heat of injera liquid = 2,3 kJ/kg.K
T1= ambient temperature

$$T2 = 100 - T1$$

$$\mu = ((2.3 * T2*I) + (W*2256)) / (F*10)$$

Indoor Air Pollution Measurements in Tigrai/Ethopia Date: Test No.: .

Village name	:	
Family name	:	
Cooks name	:	
Testers name	:	
CO Diffusion :		
Time started:	Time ended:	PPM:
Shade Particle Test:	*Time:*	
No. of Pumps:	Shade No.	Aceton Test
TSP Particle Test:	*Time:*	
No. of Pumps:	Filter No.:	
Filter ini weight:	Filter weight:	TSP:
Exhaust measurement	*Time:*	*TL*:
CO:	O_2	TA:
CO Real Time:		

Remarks:	Time	PPM CO	Remarks:	Time	PPM CO

General Data Questionnaire, Indoor Air Pollution Training 1994, Makale / Tigrai

General data:	Household No.	
	Village name	
	Family name	
	Interviewees name	
	Family size	
	No. of children	
Cash income from:	Farming	
	Stone cutting	
	others	
Ownership:	Do you own cattle	
	If yes, do you have more than 4 cattle	
	Which type of crops do you grow on your land	1. 2. 3. 4.
Fuel use:	During which months of the year do you use dung	
Dung	Where do you gather dung	
	How much time do you spent	
	How much do you gather each time	
	Do you use less dung during the rainy season	
Sorghumstalks	Which months of the year do you use sorghumstalks	
	Where do you gather the stalks	
	How much time do you spend gathering	
	How much do you gather	
Charcoal	Which months of the year do you use charcoal	
	Amount of charcoal bought per month	
	How much is spent for charcoal / month	
Wood	Which months of the year do you use wood	
	Amount of wood gathered	
	Amount of wood bought per month	
	How much is spent for wood per month	
other fuels	Do you use any other type of fuel; name it	
	Which months of the year do you use it	
	Amount of other fuel gathered	
	Amount of fuel bought per month	
	How many Birr do you spent for this fuel	
Fuel handling:	Where do you store the fuel in the rainy season	

	Do extinguish remaining fuel after cooking	
Food preparing:	How often do you bake injera in a week	
	How many injeras do you bake each time	
	How often do you cook sauce per day	
	For how many people	
	How often do you bake Ambasha	
	Do you prepare other foods, name it	
	If yes, how often	
	Do you use the stove for other purposses than cooking	
	If yes how often	
	Do you use a lid while cooking	
	Do you like kitchen work	
	Did you change your cooking habit because of fuel problems	
	If yes do you cook less often,	
	do you cook different types food	
	do you eat less food	
Health problems:	Do you have health problems caused by the smoke	
	If yes, do you have sometimes headache,	
	do you have eye problems	
	do you have lung problems	
	or name other symptoms	
	Did you have any accidents while cooking	
	How important are problems from smoke in relation to other problems	
If women have a chimney:	Who told you to built a chimney	
	Who constructed it	
	Do you want to construct it the same way again	
If no chimney is installed:	Did you see or hear about chimneys before	
	Do you want to construct one	
	If yes, why didn´t you already	
Utensils:	Mtad purchased when	
	Purchased where	
	Price	
	Do you own a Fornello	
	When did you purchase it	
	What was the price	
	Which fuels do you use with the Fornello	
Observations:		
Injera Stove	Construction	

	Height	
	Diameter Injera	
	Exhaust outlet	
	Door opening	w*h
	Chimney to inside/outside	
	Chimney length	
Sauce Stove	Combined w/injera	
	Construction	
	Height	
	Diameter pothole	
	Height potsupport	
	Door opening	w*h
	Main fuel used	
	Pans used	
	Material	
	Height	
	Diameter	
Ambasha Stove	Combined w/injera	
	Construction	
	Height	
	Diameter baking metal	
	Door opening	w*h
	Main fuel used	
Kitchen:	Location of the kitchen	
	Shape of the House	
	Type of roof	
	Door to close	w*h
	Area of the kitchen	m²
	Height of kitchen	m
	Room volume	m³
	No. of exhaust outlets	
	Windows	

C. Efficiency and Consumption Tests and Protocols

Efficiency and Consumption Tests

It is recommended that efficiency testing procedures are standardized so that results can be compared. Procedures and results must also be reproducible and well documented. Furthermore, efficiency tests should take into acount the cooking practices of a given region or country. Since these factors vary widely, the requirements for the measurement of stove efficiency are often very different. To resolve this problem, international standards for testing the efficiency of wood-burning cookstoves were developed at a Volunteers-in Technical-Assistance (VITA) Conference in 1982 in which major donors and institutions of Improved Stove Programmes were involved. At this conference, three test procedures were established, that will be described in detail on the following pages. These three testing procedures are not to consider as three alternative but complementary tests with different objectives:

- Water Boiling Test
  Objective: to compare the technical efficiency (%) of the traditional stove with the one of the improved stove. Efficiency means here the heat (energy) utilized for boiling water.

- Controlled Kitchen Test
  Objective: to test the stove according to local conditions (preparing local meal) and to compare the specific wood consumption (e.g. kg wood per kg meal prepared) of the traditional stove with the one of the improved stove.

- Wood Consumption Test
  Objective: to assess the actual wood consumption in the field (kg per day per household and person) either of traditional or improved fuel use.

Note: Inspite of these standardized test procedures and calculations you will find regional modifications and little deviations from the presented formulas depending on special cooking habits, fuel use, the duration of the measurement of the simmering phase or different ratings of evaporated water (i.e. in the case of boiling `dolo` in Burkina Faso or the production of sirup of palinfruits in Thailand). These deviations must be inquired into before testing is begun. In West African Sahel Countries, see the definition of the `rendement thermique", `Consommation specifique" et `Puissance` in the "Test d'eboullution de Feau - Methodologie pour foyers @ bois, CILSS, Ouagadougou, 1986`. Be careful with translations: the word "efficiencies", used here in a more global sense by introducing the three test procedures, can not always be translated as `rendement` in French. It is only equivalent to the word "efficiency" in the context of the waterboiling test.

Sources:

- VITA, Testing the efficiency of wood-burning cookstoves, Arlington, May 1985
- FAO, Guidelines for the Monitoring of Pilot Stove Development Schemes, Rome 1985
- Association Bois de Feu, Manuel pour rrealiser des enquetes de consummation de cornbustibles en milieu dornestique, Aix-en-Provence, Paris 1986
- FAO, Guidelines for planning, monitoring and evaluating cookstove programmes,
- Rome 1990

Waterboiling Test

Characteristics: The Water Boiling Test measures efficiencies during the high power phase when water is brought to the boiling-point.

Water Boiling Test results should provide reliable comparisons as long as the producers are not varied, and are well documented. Consistency in seemingly minor matters, such as use or not use a lid, the type of pots, and fire maintenance, are important for the results.

Objectives:
- to compare the efficiency of stoves (traditional and improved) under similar laboratory conditions
- to measure the wood consumption of a stove that is needed to boil water
- to analyze the influence of different parameters of the stove-pot-system on wood consumption

- to measure the stove's quality of heat transfer

Actors: - trained project staff/ technicians

Equipment:
- a balance for measuring fuelwood and mass of water
- a thermometer
- a chronometer or a watch for measuring the time from the starting to the boiling-point
- a hygrometer
- form for recording data and calculations (see next page)

Advantage: - theoretically, the overall efficiency in percentage of different stove models can easily be compared because of the quasi-standardization of the testing procedures and calculation

Disadvantage:
- cooking is only simulated by boiling water
- the real situation of cooking a traditional meal is not considered
- cooking habits (i.e. long simmering phase for beans that consumes a lot of wood) are not respected

Controlled Cooking Test

Characteristics: The Controlled Cooking Test - also known as Standard Meal Test - was developed to reflect efficiencies achieved in cooking. In the Controlled Cooking Test, a regular meal representative for a region or country is cooked to simulate actual cooking procedures carried out by local households. Cooking efficiencies derived from these tests should correspond more closely to actual household efficiencies. That means, the technical efficiency of the stove is tested in relation to his cooking function. Given the many variables in the Controlled Cooking Test that could affect efficiency results, these tests require careful measurements of ingredients and documentation of pot sizes, pot types, fuel and sequencing of procedures by the cooker.

Objectives:
- to measure the specific wood consumption of traditional and improved stoves during the preparation of a local meal
- to compare the specific wood consumption of different stoves while preparing the same local meal with the same quantities of food, ingredients and fuel to identify deviations in the specific wood consumption and
- to identify the influences that effect those deviations (e.g. techniques, handling, etc.)

Actors: - trained project staff

Equipment:
- a balance for measuring fuelwood, food, water
- a chronometer or a watch measuring the time from the beginning to the end of cooking
- a thermometer
- a hygrometer
- form for recording data and calculations (see next page)

Advantages:
- reflects technical capability and efficiency to serve local cooking functions (cooking, baking, heating, etc.)
- reflecting cooking habits and real field conditions, the Controlled Cooking Test gives more information than the Waterboiling Test (which in this sense is merely a "specific Controlled Cooking test, boiling water")

Disadvantages:
- analysis of efficiency is limited
- unlike the Water Boiling Test, tests are not comparable world-wide because the efficiencies depend not only on technical parameters (stove models, pot sizes, etc.) but also on the specific heat capacity of specific food and local cooking tradition.

Wood Consumption Test

Characteristics: The implementation of the Wood Consumption Test is most efficient if it is used for individual case studies in households where stoves will be introduced. It needs to be done two times:

1. before a stove programme or project is started (to record traditional stoves)
2. after the adaption of an improved stove.

The Wood Consumption Test incorporates all field parameters, though it is more realistic with regard to the assessment of changes of local household fuel consumption. The wood consumption is usually expressed in kg fuel per person and day. Using individual families and `normal` household conditions, household cooks prepare their usual meals on traditional and/or improved stoves. These tests also show the impact of a new stove on the overall use of energy by the household. Observations of the real cooking habits of individuals allow reflections of potential differences between the real fuel savings through improved stoves and the fuel savings predicted by the Waterboiling Test in the laboratory. This test can therefore be far more than a measure of stove efficiency through combining scientific data gathered with active household participation. It has to be done over a period of seven days.

Objectives:

- to compare the wood consumption of traditional and improved stoves concerning
- the impact of the use of improved stoves on fuel consumption by the household and fuel savings (through technical and operational improvements)
- to demonstrate the fuel saving potential of a new stove in the household, and to understand, illustrate and to correct operational practices of stove users

Actors:

- women/cooks of households
- trained investigators evaluate (interviewing, observing and measuring)

Equipment:

- balance for measuring fuelwood
- forms for recording data and calculations (see next page)

Advantage:

- shows the wood consumption
- and the real fuel saving potential of new stoves
- under field conditions

Disadvantage: - tests cannot he compared like Water Boiling Tests because the individual fuel saving rate depends on parameters like the number of household members which eat together, correct use of new stove, multiple use of the stoves (i.e. water heating. cooking of traditional medicine, etc.).

Waterboiling Test Protocol

Test No.:.. Date:..................... Operator ....
Locality :.. Height: .... (m) Temperature: ....°C
Pressure:.. Wind:.................... Relative Humidity (RH):.............%
Moisture content of wood (dry wood basis): x =.................

Type of pot: .... Sketch of stove, grate and pot (dimensions):
Outer Diameter of pot: ....(mm)
Height of pot: ....(mm)
Weight of pot:..(mm)
Capacity of pot:..(litres)

Type of stove:
Inner diameter:..(mm)
Wall thickness: ....(mm)
Weight of stove: ....(kg)
Type of grate:

Type of wood:
Weight of wood:...(kg)
No. of pieces:
Diameter: and length:...(mm)

Use small wood sticks to start the fuel burning = starting fuel: A1=...................(kg)

Water temperature (start): T1 =..................(OC)........ Water temperature (boiling):......T2=.....°C
T2 - T1 =........ ....°C
time till boiling: tb = ...(min) .... (sec).................................... ....(sec)

Weight of empty pot with lid and thermometer M1 =....................(kg)
Weight of pot with 2/3 capacity of water, lid and thermometer at start M0 =....................(kg)
Weight of pot with 2/3 capacity of water, lid and thermometer at boiling point M2 =....................(kg)

Boiling water produced: M3 = M2 - M1 (kg)=............................(kg)

Weight of wood at start: B1=................................(kg)
Rest of wood at boiling point: B2=..............................(kg),
Remaining charcoal at boiling point: C2=..............................(kg)

Dry wood consumption: WC ....(A1 + B1 - B2) x (100% - x%)) -1,5 x C2 =..............................(kg)

Power : Ph= WC X 19000/tb (sec) = ...kW)
Efficiency E ={(4,2 x M3 (T2-T1))+((M0-M2) x 2260)}/WC=...........................x100= (%)

Controlled Cooking Test Protocol

Test No.:.. Date:.................... Operator...
Locality :... Height:................ (m) Temperature:...................................(°C)
Pressure:.. Wind:................... Relative Humidity (RH): ....(%)
Moisture content of wood (dry wood basis): x =............................

Type of pot: .... Sketch of stove, grate and pot (dimensions):
Outer Diameter of pot: ....(mm)
Height of pot: ....(mm)
Weight of pot:..(mm)
Capacity of pot:...(litres)
Type of stove:
Inner diameter:..(mm)
Wall thickness: ....(mm)
Weight of stove: ....(kg)
Type of grate:
Type of wood:
Weight of wood:..(kg)
No. of pieces:
Diameter: and length:...(mm)

Use small wood sticks to start the fuel burning = starting fuel: A1=......................(kg)

Food temperature (start): T1 =..................(°C).......Water temperature (boiling):.......T2=....... (°C)
T2 - T1 = ...(°C)
time till boiling: tb = ...(min).....................(sec)..(sec)

Weight of empty pot with lid and thermometer...M1 =....................(kg)
Weight of pot with 2/3 capacity of food, lid and thermometer at start ....M0 =....................(kg)
Weight of pot with 2/3 capacity of food, lid and thermometer at boiling point............................M2 =....................(kg)
Food prepared/cooked M3 = M2 - M1 (kg)

Weight of wood at start: B1=..............................(kg)
Rest of wood at boiling point: B2=..............................(kg)
Remaining charcoal at boiling point: C2 = (kg)

Dry wood consumption: WC = ((A1 + B1 - B2) x (100% - x%) -1,5 x C2 =................(kg)

Spec. Stand. Consumption: SSC = WC / M3 =.......(kg) dry wood/kg food prepared

Wood Consumption Test Protocol

Basic data No. of test:......................................
Town/ Village:...District:..
Name of the household:...Time of passage:.............................
Name of evaluator:..Date of beginning of survey:...............

Survey

Day of survey	FIRST FUEL		SECOND FUEL		
	rested	added	rested	added	OBSERVATIONS
1		................kg		..................kg	(e.g. No. of eaters, food cooked meals per day, etc.)
2	.....................kg	................kg	...................kg	..................kg	
3	.....................kg	................kg	...................kg	..................kg	
4	.....................kg	................kg	...................kg	..................kg	
5	.....................kg	................kg	...................kg	..................kg	
6	.....................kg	................kg	...................kg	..................kg	
7	.....................kg	................kg	...................kg	..................kg	
8	.....................kg		...................kg		

Calculations

	FIRST FUEL	SECOND FUEL
Total fuel added:	....................kg	.....................kg
Fuel left last day:	....................kg	.....................kg
Total fuel consumed during survey:	....................kg	.....................kg

Duration of survey: ....days

Total consuumption per day per household: kg .... kg

Number of persons eating meals together
in this household:...................persons

Consumption per day per person: ....kg/P .... kg/P

Comments of evaluator: (duration of cooking, operational habits, etc.)
....
....
....
....

D. Statistical Sampling Methods

Statistical Survey Methods

Sampling

Method: Sampling is a simplified statistical process, because not every member of a population or of the stove users need be interviewed and/or observed before generalizations can be made about the target population. Instead, samples may be drawn and, if they are drawn correctly, results from the study of samples will accurately represent the wider populations from which the sample is drawn. The process of sampling greatly reduces the time and money required for investigation.

A sampling frame is a list of sampling units - such as individuals, households, families or stove-producers - in the population from which a sample is selected. Urban centres, villages, rural regions or all stoveproducers are possible sampling frames.

The size of the sample required is decided on the basis of the characteristics of the target population, the topics being studied, the completeness of the sampling frame, the resources available to the evaluator and/or the project, and the degree of accuracy necessary for the project to be worth doing all.

Types of sampling: Random sampling means that every individual in the population has an equal chance of being selected for the sample; selection occurs by chance.

A systematic sample is a specific type of restricted sample. Every *n*th unit is selected, after a number between 1 and n is randomly chosen as the starting point. Systematic samples are considerably quicker and cheaper to draw than other samples.

Stratified samples are selected to ensure that appropriate numbers of members from small subgroups are included in the sample. The population is stratified through the creation of a sampling frame (i.e. town) for each stratum (i.e. socioeconomic groups, districts, professional groups, etc.) and a sample of each is selected. The percentage drawn from each stratum may be the same or different, according to the needs of the project.

A cluster sample involves the selection of groups or clusters of sampling units. All of the units in the clusters are then studied (i.e. all households in one or n selected villages or districts of the capital). The clustering of respondents greatly reduces the cost of data collection, for each `visit` to village or `entry` into an institution (i.e. clustered metal-workshops on a handicraft market) guarantees many potential respondents.

Non-random sampling is discouraged, as it is risky to generalize from non-random samples in order to draw larger populations (i.e. in the case if you choose conclusions about households of relatives of the project staff only).

Purposive samples, whereby the evaluator chooses individuals presumed representative of the population (i.e. to test the social acceptability of stoves you interview the village chief and/or his wife).

Creating a sample is not easy. In the frame of large scale household energy projects you will usually find a wide range of cooking practices, disparities in wealth, political participation, access to fuel, several different ethnic groups, an unequal balance of stove users and non-users. All these factors could reflect high variations and extremely different degrees of stove dissemination, stove acceptance, different fuel-saving rates, etc.

A sample is a smaller representation of the target population, therefore it must be both:

- representative of the total population and
- statistically significant

Although this guideline cannot fulfill expectations of a complete handbook of empirical me-thods, it will further provide an orientation on "How to choose samples for different types of household energy projects and target groups", and `How to prevent errors in choosing a sample`.

Example 1: Dissemination approach and monitoring -
Statistical problems with purposive or non-random samplings

There are household energy projects where the sampling is automatically purposive. For example, if the project implements action programmes for villages, the people who receive the stove are chosen by the community and/or the village chief. Or, in the case of a project's basic-needs approach, a group that has little access to resources (landless, unemployed) may be chosen to receive a new stove. Thus a representative sample may not be involved in the monitoring. It is then very difficult to draw any general conclusions about acceptability, or the effect on household fuel consumption for the whole population. Therefore it is important to know how the stove user differs from the rest of the population if definite conclusions are to be drawn.
The same problems can arise with non-random samplings, e.g. if only relatives of the project staff are monitored in order to economise on personnel, financial resources, and time.

Example 2: 50 households from nearly homogenous areas

For areas where patterns of fuel use, income levels, cooking practice, kitchen types, are nearly homogenous, a sample of 1% to 2% of total households in the area or a maximum sample of 40 to 50 households, chosen at random, is sufficient to deliver statistically significant results. Such a homogeneity is rarely observed. That is why such a small sample can only be chosen in relatively "isolated" project-areas, like a group of neighbouring villages with about 100 households each. This is very rarely observed, therefore the sample must he more extensive.

Example 3: Small dissemination requires total sampling

When less than 300 households should be investigated - e.g. during the starting or pilot phase - all households should be studied, as great variations in performance and acceptance are usually observed. (It could be useful to note either the home address of customers, and/or do encourage them to participate in monitoring by reducing the stove price so that their houses will be found again more easily).
Above this number, random samplings are best used.

Example 4: 50 households from each sub-group of a stratified sample

Stratify your sample into existing sub-groups (ethnic groups, income groups, rural areas, etc.) on the basis of accurate baseline data or official census information. After having divided the population into homogenous groups (= stratified the sample), the sample can be calculated by multiplying the figure 40-50 by the number of groups. The sample can be chosen at random.

Example 5: Starting phase: 30% in rural areas with high variances between villages

During the initial field test phase (starting phase and pilot phase) most projects will find high variances within a village or between villages in relatively small areas. The following procedure is therefore recommended for the starting phase in rural areas. For example: three villages with around 100 households each, that are either different ethnically, socio-economically and/ or ecologically, are chosen by the project for pilot activities. 30% to 50% of households are chosen at random (= 100 households) and are offered the use of an improved stove. The performance and acceptability are monitored. Taking such a large sample at the beginning ensures a high probability that all different groups will be represented.

Example 6: Stratification by income and access to fuelwood in urban areas

Studies in urban household energy projects show that the urban population can largely be stratified according to income level and physical, financial and legal access to fuelwood, as these factors appear to have the greatest influence on stove acceptance. Each of these groups can be subdivided into three categories (i.e. high, medium, low income; easy, difficult, no access).
If each group must have 40 to 50 households, chosen at random, then the minimum sample size is 6 x 40-50 = 240 to 300 households. These figures of 240 to 300 households will guarantee statistical significance and will show the influence of income on stove acceptance).
It has been found that around 10% to 20% will neither participate or cooperate, nor fill out questionnaires, nor move. Add these 10% to 20%, so that the total sample will then include between 300 and 400 households.

Example 7: Socio-geographic, demographic stratification quoted by quarters in an urban area

In urban areas, random sampling can also be conducted on the basis of socio-demographic stratification. For example, if there are types, or even defined categories of districts that represent socioeconomic sections of a population such as: outskirts with rural and agricultural standards and physical access to fuelwood, marginal and peripheral squatter areas inhabited by landless and unemployed families that must buy the fuelwood, semi-peripheral residential areas inhabited by middle income groups that purchase wood on local markets, central residential areas of high income groups and governmental employees who buy wood in larger quantities and who have transport facilities for buying „cheap" wood in rural areas, etc..
It is important to find out whether such a socio-geographic stratification of districts has already been established by official censuses or basic national/regional socioeconomic and/or demographic studies (i.e. expenditure surveys of different urban districts).
Then choose 50 households in each category of district at random and add 10% to 20% of the total households to prevent a high deficit loss.

Conducting Interviews

Method: a face-to-face interpersonal situation in which the evaluator asks responders questions designed to obtain answers pertinent to the STUDY indicators `What to measure". The questions, their wording and their sequence define the extent to which the interview is structured.

types of interviews: The most structured form is the scheduled-structured interview, in which the questions, their wording and their sequence are fixed, and are identical for every responder. It ensures that if variations appear between responses, they can be attributed to the actual differences between the responders and not to variations in the process of interviewing. In this case standarized questions are used.

The nonscheduled-structured interview allows responders considerable liberty in expressing their definition of the situation, although the encounter between the interviewer and interviewees is structured, and the major aspects of the study are explain to them. The nonscheduled-structured interview permits the evaluator to obtain and to registrate details of personal reactions, specific emotions and opinions. The trained interviewer, having previously studied the situation, is alert and sensitive to inconsistencies and omissions of data that may be needed to clarify the problem. In this case, open questions are used.

A nonscheduled interview is a nonstructured or nondirective form of interviewing. Here, no prespecified set of questions is employed, nor are the questions asked in a specific order. Furthermore, no schedule is used. With little or no direction from the interviewer, interviewees are encouraged to relate their experiences, to describe whatever events seem significant to them, to provide their own definitions of their situation and to reveal their opinions and attitudes according their own perception. The interviewer has a great deal of freedom to probe various areas and to raise specific issues during the course of the interview.
In this case, a questionnaire guideline can be used or not, but in any case the important aspects must be present in the interviewer's mind.

A questionnaire should be constructed with both open and standardized questions so that all necessary (and also subjective) informations given by the interviewees are covered.

Open question

Method means: interviews are asked to give an opinion on a subject. They are free to respond to a question in whichever way they like, and are not limited by predefined codified answers.

does not mean that: responders are obliged to select one or more of the specific categories provided by the interviewer

advantages: open questions can be used when not all the possible categories of answers are known, or when the interviewer wishes to see what the interviewee views as appropriate categories. For example, the open question, `what would you like to change about the improved stove?" (indicator: symbolic or cultural values) may reveal some information that the researcher did not anticipate, in addition to the already known.

Open questions allow the responder to answer adequately, and in as much detail he/she likes, and to clarify and qualify his or her answer.
Open questions can be used when there are too many potential answers

Standardized question

Method is: a question in which response categories are specified, and/or a fixed alternative supplied. The responder should answer `yes` or `no` or choose from a series of answers,

is not: a question that allows for free response from the interviewee.

advantages:

- the answers are standardized, and can be compared from household to household
- the answers are much easier to code and analyze, and can be directly coded from the questionnaire, thereby saving time and money
- the interviewee often understands the meaning of the question better
- the answers are relatively complete (if all appropriate categories of answers are provided)

Observation

Method: the primary technique for collecting data on nonverbal behaviour. It involves not only visual data collection, but also data collection via the other senses, such as hearing, touching or smelling. The use of the observational method neither precludes nor excludes simultaneous use of other data-gathering techniques, such as interviews. Often, it represents a supplementary method to others.

types of observation: participant observation means the observer is a regular participant in the activities being observed, and that his or her dual role is generally not known to the other participants. For example, a blacksmith, trained and/or employed by the project, trains a group of blacksmiths in his own original environment. Simultaneously, he controls the impact of the training by observing the capability, behaviour and opinions of each participant in order to report the results to the project.

Nonparticipant observation, on the other hand, means that the observer does not participate in group activities and does not pretend to be a member. Normally, he/she is a stranger in the natural environment of the observed persons.

advantages:

- Observation allows for an in-depth understanding of events or issues
- It allows the researcher/evaluator to observe the targeted individuals/groups in their natural environment
- Method is flexible and allows the researcher to be surprised and/or to concentrate on any variables that prove to be important
- It is not restricted like a standardized questionnaire or interview
- `Field notes` can even be easily recorded and analyzed by modern electronic media, i.e. photographs or videotape recording the construction of stoves or their use during a cooking demonstration

disadvantages:

- Observation represents a potential for loss of detachment and loss of objectivity. Lack of control over extraneous variables that may affect the data as well as difficulties of quantification
- The evaluator is directly exposed to the subjects, which may he emotionally difficult
- There is a potential for floundering if the researcher obtains little information of value
- Data collection may suffer from problems of reliability and validity

Documentation

Method is: the primary technique for reporting data

aspects of documentation and their advantages

The documentation of study results is very important for the internal and external flow of information and the proceeding reflection and discussion of results.

The documentation can be efficient if the following aspects are respected:

- A survey record can be very useful to present `what you evaluate, where, by what methods and for how long`. This survey record can also be used as the introduction of your report.
- Structure the questionnaire in a logical way in order to facilitate the interview. Additionally, a well-listed questionnaire can be used to establish the headlines of your table of contents.
- Tables and figures can make it easier to visualize and present complex data, not only for internal use and discussion, but also for the presentation to outstanding persons or institutions (i.e. funding organizations). They could be actualized periodically which does not mean to establish new documents after each studyactivity, but only to add new results.
- Percentage values should not be used for a total sample which includes less than 50 units (if the 50 cases do not present the total sample frame). Percentages would not reflect a real representation. In that case, it would be better to mention the total units, i.e. 10 out of 50 units (households) instead of 20%.

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F. Index of figures, equations and tables

List of figures

List of Equations

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