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Ventilation of dry toilets

Case Study: Close-Ups of Various Installations in Uganda

Diplomarbeit
zur Erlangung des akademischen Grades
Diplomingenieur (FH) für den Studiengang
Building Technology and Management

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Kurzfassung Deutsch

Thema der Arbeit: Ventilation of dry toilets

Stichworte: Ecological sanitation; Trockentoiletten; Natürliche Lüftung; Erzwungene Lüftung

Das Ziel dieser Arbeit ist es Möglichkeiten aufzuzeigen, die eine Verbesserung zu derzeitigen Ventilationsstandards, Ugandesischer Trockentoiletten, darstellen. Hierfür wurden, über einen Zeitraum von drei Monaten (März – Juni), eine Vielzahl dieser sanitären Einrichtungen, in Hinblick auf deren gesamtheitliche Gestaltung und im speziellen auf deren Ventilationssystem, untersucht und analysiert.

Jede Einheit wurde an drei aufeinander folgenden Tagen untersucht. Dabei wurden die Toiletteninnnen- und außentemperatur, die Windrichtung, allgemeine Wetterbedingungen und der Luftstrom in der Hockform (squatting pan), welche die Verbindung zwischen dem Fäkalienspeicher und dem Benutzerbereich darstellt, aufgezeichnet. Diese Daten sowie die theoretischen Grundlagen repräsentieren das Basiswissen in Hinblick auf den Entwurf und Einsatz einiger Lüftungselemente und Geräte, wie z.B. ein Wind oder Strom betriebener Zugbeschleuniger, Luftführungselemente oder ein selbstschließender Hochformverschluß.

Grundsätzliche Überlegungen und Empfehlungen, welche aus dieser Diplomarbeit hervorgehen, sollen eine Grundlage beziehungsweise eine Unterstützung für weitere Entwicklungen darstellen und zukünftig errichtete Trockentoiletten speziell im Beriech der Ventilation verbessern. Damit soll ein Beitrag zur Qualitätssteigerung der gesamten Toilette geleistet werden, um die Akzeptanz dieser alternativen Abwassertechnik für die Zukunft weiter auszubauen.

Abstract

Topic of the diploma thesis: Ventilation of dry toilets

Keywords: Ecological Sanitation; dry toilets; natural ventilation; forced ventilation

This thesis aims at showing possibilities to improve ventilation standards of dry toilet facilities. Therefore, numerous structures were monitored over a period of three months, from March to June, in the south-western districts of Uganda.

Each facility was observed three days in a row, capturing the inside and ambient temperatures, wind directions, general weather conditions and the air flow in the squatting hole, which represents the connection between the storage vault and the user area. This recorded data and the theoretical fundamentals, represented the basic knowledge of further deliberations, regarding the modulation and implementation of various elements and devices, such as wind or electrical power driven flow accelerators, capture elements and additional design recommendations.

The considerations and recommendations of this paper should support further development and improve future toilet structures in view of ventilation practices and design purviews. It should therefore contribute to a higher quality and acceptance of the dry toilets in the long term.

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1 Introduction

1.1 Preface

The last decades of the industrial nations were marked due to a rapid economical development and an increasing standard of living. But for a very long period of time it was denied that many of these benefits and attainments were financed at the expense of the environment. Sustainable solutions have not been developed yet or were not seen as an important precaution. On the one hand because of the financial burden and on the other hand because of the slow and invisible destruction of the nature.

Many people and their children have to live in highly polluted environments all over the world. Rural, urban and peri-urban areas in developing countries are the most effected. Rapid urbanisation, fast population growth, illegal settlement, lack of space, insufficient financial sources and the lack of town-planning measures are some examples, which contributed to stress the natural environment with unsafe emissions. The brief abstract below, published by the World Health Organization (WHO), exemplifies the current situation in terms of water supply, sanitation and health worldwide.

"Around 1.1 billion people globally do not have access to improved water supply sources whereas 2.4 billion people do not have access to any type of improved sanitation facility. About 2 million people die every year due to diarrhoea diseases, most of them are children less than 5 years of age. The most affected are the populations in developing countries, living in extreme conditions of poverty, normally peri-urban dwellers or rural inhabitants. Among the main problems which are responsible for this situation are: lack of priority given to the sector, lack of financial resources, lack of sustainability of water supply and sanitation services, poor hygiene behaviours, and inadequate sanitation in public places including hospitals, health centres and schools. Providing access to sufficient quantities of safe water, the provision of facilities for a sanitary disposal of excreta, and introducing sound hygiene behaviours are of capital importance to reduce the burden of disease caused by these risk factors."[1]

With increasing population density along with expanding cities, the conditions of these living areas will grow worth. Therefore, the needs of self-sustaining, affordable and safe sanitation systems, which are tailored to local requirements, are obvious.

However, many research scientists are working on various strategies, trying to cope with acutel and future challenges. Yet, due to a lack of considerations for example the different cultural behaviours beside areal and temporal material flows, overall solutions have to be seen as an invalid basic approach.

Recent modernizing concepts in so called developing countries still follow a "top down" strategy. Although various accounts talk about project failures with massive impacts on the affected environment and its inhabitants, old fashioned schemes are still being implemented. A "bottom up" strategy, taking local knowledge, circumstances, empowerment on a local scale as well as an overall view of material and energy flows into account, only slowly finds its way to recognition by national and international politics. The different local conditions are aiming at flexible and locally adapted solutions.[2]

To approach these solutions, the concept of Ecological Sanitation is introduced as a way to tackle the problem of lacking sanitation worldwide. It does not favour a specific technology, but constitutes a philosophy in handling substances that have so far been seen merely as wastewater and organic waste for disposal.

1.2 Sanitary Engineering towards Building Technology

Since conventional sanitation schemes are coming under increasing criticism for economical (prime costs, operating costs…) and ecological reasons (pollution, loss of nutrients…), "front of pipe" technologies are getting more and more popular.

Conventional sanitation systems are mostly based on an "end of pipe" technology, which means that water is used to transport human defecations and afterwards led through sewage pipes out of the household into a hooked up treatment plant or waters (globally seen 90% without any treatment).

The "front of pipe" technology proceeds on the fundamental idea to separate material flows and to treat them where they are produced. That means water and sanitation related techniques and structures are moving towards respectively into the building. Complex problems, which will undoubtedly appear by connecting these hardly related disciplines, for example by storing or processing the human excreta in a dwelling house, need interdisciplinary knowledge and considerations to find appropriate solutions.

As a result of these deliberations the Burgenland University (Department for Building Technology and Management) and the University of Natural Resources and Applied Life Science (Institute for Sanitary Engineering and Water Pollution Control) in Vienna, decided to cooperate on various levels in order to coop with already existing and future challenges. Hence, I was able to take part at a long term development project in Uganda/Africa initiated by the Austrian Development Co-operation.

The Austrian Development Co-operation (ADC) focuses on projects in regions with a poor standard of living and insufficient infrastructure. The main goal of the ADC is "the improvement of human living conditions for the poorest and the world most discriminated."[4]. Other goals are split in various categories, like the water-, health-, tourism-, education-, renewable energy and the micro-, small - and middle company support sector). Due to limited financial resources, the water activities in the water sector concentrate on the basic necessities in water supply and sanitation. The main aim of the ADC Water Sector Policy is to ensure the long term support of the drinking water along with the improvement of sanitation structures.[3]

1.3 Objectives

The main target of this diploma thesis is to improve future ventilation installations and to modulate adapted, region tailored solutions. Close-ups, series of measurements of different types of dry toilets and the consultancy of relevant institutions, companies and associations, represent the basic knowledge for further development and constructions.

It's aimed to find solutions in view of non electricity (ventilation) components on the physical basis theory of natural ventilation to meet the needs of regions affected by an insufficient infrastructure, but also to find solutions including electrical components. Furthermore the capability of state of the art technologies, based on the physical theory of forced ventilation has been taken into account. Due to this approach the quality of defecation should be increased by reducing disturbing odour in the user chamber, which in the long term contributes to a higher acceptance of dry toilets.

The specific questions of this research are:

- What is the current aeration situation of observed dry toilets?
- What are the areas of weakness in existing standards?
- What are possible reasons for malfunctioning/functioning?
- How do alternative, affordable and simple technologies look like, by taking regional material availability and the standard of infrastructure into consideration?

There are many methods of controlling indoor air pollution, including control, air cleaning and dilution with uncontaminated air. The choice of method, for any given situation, will depend upon practicability, source location and distribution, and cost.

1.4 Outline of the thesis

- Chapter two gives an overview of the country of Uganda. It consists of geographical, climatical, social and political segments.
- Chapter three gives a brief overview about ecological sanitation; the main principles of EcoSan and the potential of reuse sanitized urine and faeces.
- Chapter four gives an overview about the development of ventilation practices and sums up the demands, tasks, requirements, state of the art ventilation practices, aerial guidance principles concerning the usage of ventilation systems and describes calculation basics regarding the air duct dimensioning and the appearance of external pressure losses, such as the pressure loss due to friction, the pressure loss due to resistances and the pressure loss through installations.

- Chapter five analyses the used research techniques. It consists of the basic information on survey methods and characterizes the actually applied interventions.
- Chapter six describes the present situation in the project area and illustrates results of the direct observations.
- Chapter seven gives recommendations on possible technical improvements. It includes deliberations about the usage of natural forces, technical components and design.
- Chapter eight includes a summary and recommendations on further and helpful surveys.

2 Regional background – Uganda

2.1 Basic data

All following basic data according to [4].

Area:	241.138 sq. km.	
Form of government:	Presidential and parliamentary system	
Population:	22.2 m	
Main towns:	Kampala (capital)	1.200.000
	Jinja	65.000
	Mbale	54.000
	Masaka	50.000
Languages:	English, Kiswahili, Luganda and other local languages	
Currency:	Uganda shilling	
Time:	3 hours ahead of GMT	

2.2 Political background

In 1984, all territory between the Lake Victoria and the Indian Ocean became British protectorate. It included Uganda, Kenya and the islands of Zanzibar and Pemba. The colonial administrators introduced cotton and coffee as cash crops and adopted a policy of indirect rule, giving the major tribe, the Bugandas, considerable autonomy. [5]

The party-landscape witch had been created till the end of the colonist period existed mainly of three forces: the Democratic Party (DP), the Ugandan People Congress (UPC) and the Kabaka Yakka (KY)

Uganda achieved independence in 1962. The period from 1962 to 1986 was unstable and destructive. Most of the violence was ethnically directed, the Nilotic people of the north fighting the Bantu people of the south. The first government after independence was led by Kabaka (the Bugandan king) a southerner beside his Prime-minister Milton Obote, a northerner. Milton Obote seized power in 1966, only to be replaced in 1971 by his army chief Idi Amin, also a northerner. In 1979 he was deposed by exile Ugandan guerrillas and the Tanzanian army. Meanwhile the economy collapsed and infrastructure crumbled. [4]

In 1986 a military coup, executed by the National Resistance Army (NRA), brought Yoweri Kaguta Museveni into power. The National Resistance Movement (NRM), the political wing of the NRA, became the government.

Since then a careful democratisation process and a pragmatic ecological policy have resulted in praise and support by international donor institutions. [6]

2.3 Geographic

Uganda is an entirely landlocked country, about 1000 km inland from the Kenyan coast and divided by the equator in its southern third. It borders to Sudan in the North, to Kenya in the east, to Rwanda, Lake Victoria and Tanzania in the South and to the Democratic Republic of Congo in the west. (See figure 2.1)

The highest peaks are the volcano Mount Elgon in the east with 4.323 m, the Rwenzori Mountains with a height of 5.119 m and the Virunga Volcanos near the Rwandan border. Though flat, the country is high, with an average altitude of about 900 m above sea level. [7]

The bulk of the country has a tropical climate tempered by altitude. The land varies from the opulent and fertile shores of Lake Victoria in the southeast to semi dessert in the northeast.

The land is used at follows

arable land:	25%
permanent crops:	9%
permanent pastures:	9%
forest and woodland:	28%
other:	29%

Figure 2.1: Map of Uganda [8]

2.4 Climate

The majority of the country has a tropical climate. In Kampala, near Lake Victoria, the daily average temperatures range form 17°C to 28°C, in the highlands of the southwest, they range from 8°C to 24°C. [9]

Most areas have distinct dry and wet seasons and from March to May and October to November. The areas with the lowest precipitation are situated in the north and northeast, with an annual amount of 900 mm, while the wettest areas, situated in the south, get over 1500 mm.

2.5 Population

Preliminary estimates put the Ugandan population at 22.2m with an average population growth rate of 3,0 % between 1991 and 2000, but demographic patterns will be deeply affected by the AIDS epidemic. [4]

The United Nation has forecast the birth rate at 47 per 1000 population and the death rate at 20 per 1000 population. The average life expectancy is 42 years from birth, compared with a life expectancy of 51 in Kenya. [4]

Table 2.1: Population by region

Region	1991	2000
Central	4,843,594	6,185,400
Eastern	4,128,469	5,631,600
Northern	3,151,955	4,220,800
Western	4,547,687	6,172,600
All regions	16,671,705	22,210,400

About 11% Ugandans are classed as urban inhabitants. Whereas approximately 40% live in Kampala, the capitol of the country. The population density is put at 123 per sq. Km. [7]

In Uganda, 35 – 40% are Roman Catholic, 30% are Protestant, 8 – 13% Muslims and approximately 17 – 27% have local or other religious professions.

In Figure 2.2 the population distribution by age in Uganda and Austria is shown. These pyramids are an appropriate means to address different social problems of a country.

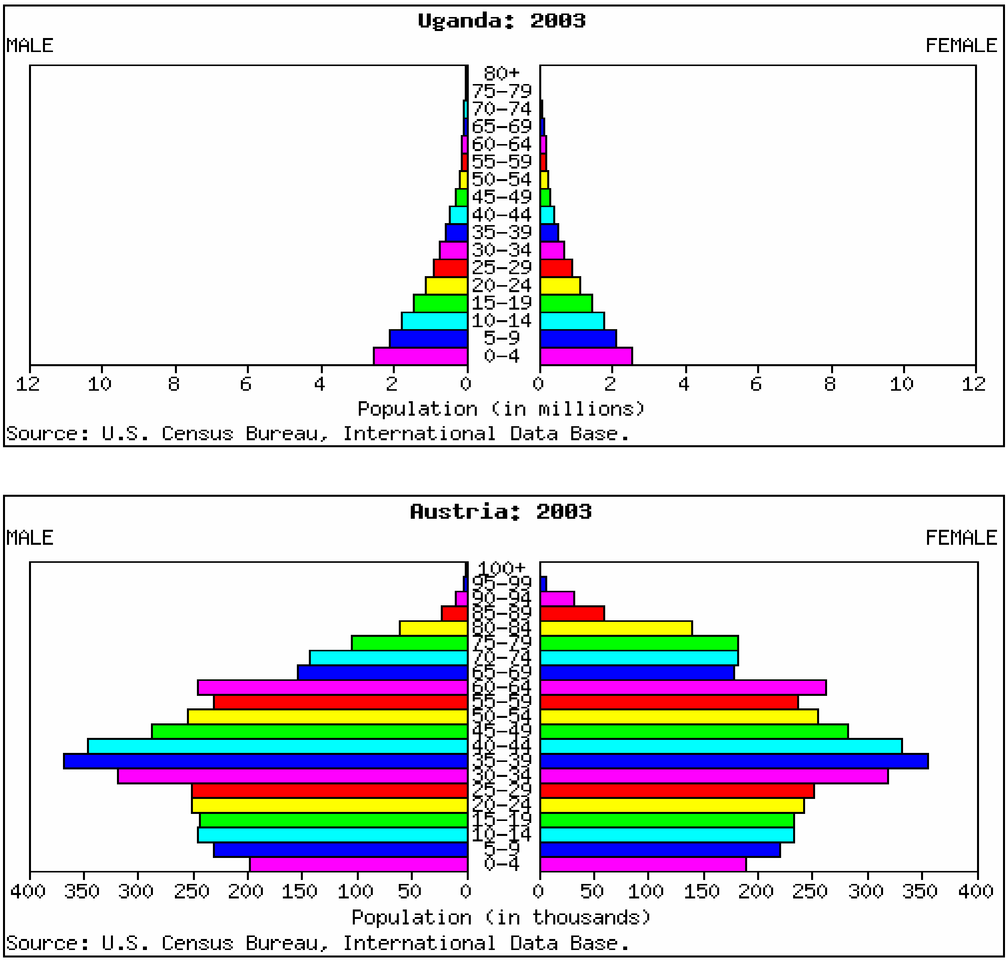


Figure 2.2: Age pyramids of Uganda and Austria [10]

2.6 Economic structure

Agriculture is the most important sector of the Ugandan economy, accounting for about 44% of the GDP, followed by the community services with almost 20% of the GDP (see figure 2.3).

The commerce and the manufacturing sector each account for about 10% of the GDP. Due to the neglect during the colonial period in favour of agriculture it had to suffer more from the instability of the 1970s and 1980s.

Economic activity mostly takes place in the south third of the country. The high rainfall intensity has a positive influence on it's agriculture beside a high population density; which supports a large number of towns.

2.7 Socio – Economic performance

Uganda developed well after the disastrous regime of Idi Amin. The Gross Domestic Products (GDP) has grown at an average rate of 5% per year and about 6,9% per year since 1990/91.

Table 2.2: Economic indicators [11]

Economy		
GNI, Atlas method (current US$)	2003	6.2 billion
GNI per capita, Atlas method (current US$)	2003	240.0
GDP (current $)	2003	6.2 billion
GDP growth (annual %)	2003	4.9
Inflation, GDP deflator (annual %)	2001	2,8
Imports of goods and services (% of GDP)	2003	27,2
Exports of goods and services (% of GDP)	2003	12,7

This development is basically reached due to the return of stable conditions in most parts of the country. Also the results of a national household survey, carried out by the Bureau of Statistics between August 1999 and August 2000, shows that Ugandans living in absolute poverty had fallen by 9%, from 44% to 35% compared to 1997/1998 the survey was carried out.

However, while development in urban areas especially around Kampala and Jinja improved, development in rural areas has lagged far behind. In northern regions the poverty level had risen to 65%, compared with 60% two years earlier.

Human Development Index (HDI) ranking of the year 2003, Uganda is listed as number 147 of 175 countries. [12]

2.8 Infrastructure

Water supply: The majority of the people draw water from unprotected sources, rainwater tanks and gravity water flow schemes. The availability of water vary seasonal and regional. During dry seasons in June/July especially seasonal wetlands dry up forcing people to travel up to 10 km for permanent water bodies. UNEP (2001) reports that only 50% of Ugandan in Urban and 35,2% in rural areas (mean 46%) have access to clean water. MoFPED [13] linked the diseases, caused by polluted water, directly to poverty. Therefore it is planned in the Ugandan Poverty Eradication Action Plan (PEAP), that 100% of the rural population should have access to safe water and sanitation by the year 2015.

Sanitation: The resent sanitation coverage in Uganda represents a poor situation. According to ÖFSE (2001) only 57% of the households have access to sanitation facilities, mainly pit latrines.

3 Sanitation methods

According to Taylor [14] sanitation systems can be characterised, depending on the usage of water or not, as 'wet or dry' systems .He also categorised sanitation systems as onsite (drop and store), hybrid and offsite (flush and discharge) systems. On site systems retain both liquid and solid excretions on or near the site, where they accrue. The term hybrid refers to systems that retain solid on or near the plot but remove wastewater. Offsite systems remove both faeces and waste water from the site for disposal or after treatment elsewhere. The most common principles, in the following progress described as 'drop and store' and 'flush and discharge', are described below.

3.1 Flush and discharge

The 'flush and discharge' type of sanitation has been widely accepted as the best sanitation method regarding hygiene of the users and is further indicated as the most common technology, especially for urban –and peri urban areas of western countries. For this system an estimated amount of around 15,000 litres of water are required to flush away about 400-500 litres of urine and about 50 kg of faeces per capita and year. [15] These figures show that flush and discharge requires a huge quantity of water respectively drinking water to swallow away relatively small amounts of waste and therefore generating a larger volume of polluted wastewater. [16] Furthermore the construction, operation and maintenance of the claimed hardware for the "flush and discharge" components (sewer, wastewater treatment, drinking water treatment) are a heavy financial burden.

Conventional sanitation systems (figure 3.1.) have even more shortcomings such as the loss of nutrients and trace elements contained in human excretion, over-exploitation of limited renewable water sources and a contamination soil, surface and groundwater with generated wastewater. [17] A relatively small amount of harmful material is able to contaminate a huge amount of pure water.[15] There are suitable techniques for wastewater treatment in the developed countries. But developing countries are usually confronted with a lack of necessary recourses, in terms of sewer line coverage, limited treatment plants and other resources. Under such circumstances, these countries, especially the emerging urban areas, face severe water pollution and sanitation problems.

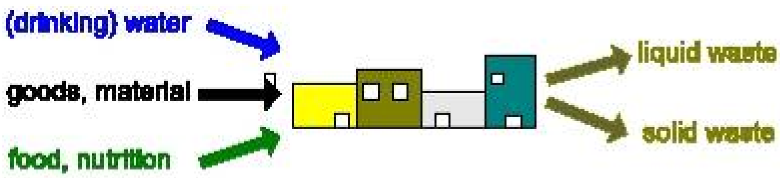


Figure 3.1.: Linear flow in a conventional sanitation system. [18]

3.2 Drop and Store

Another sanitation system widely spread in developing countries is the 'drop and store' method. The most common application in this connection is the pit latrine beside other, more or less advanced, types. Even though this type has an advantage over the previous one as waste is not flushed away but is stored at the source, it has some drawbacks. It requires access to ground, a large amount of open space, soil that can be dug, a low ground water level and a site that is never flooded. Further concerns about pit latrines are the contamination of groundwater due to soaking, fly breeding, bad odour, pit collapse or overflowing after heavy rainfalls.

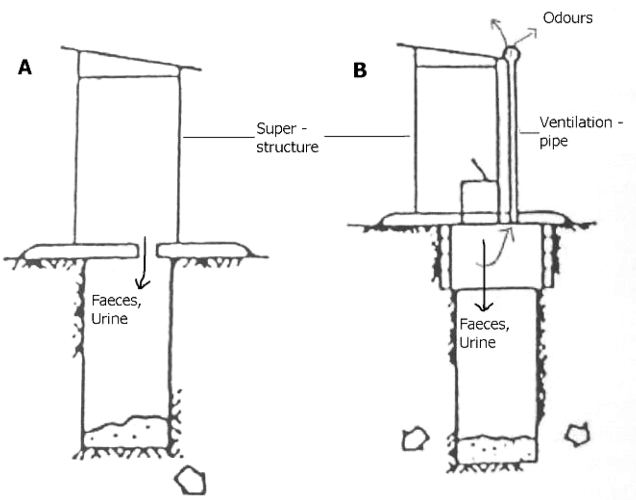


Figure 3.2.: The main principles of a pit latrine. A) Standard pit latrine. B) Ventilated Improved Pit latrine (VIP).

3.3 Sanitize and reuse

In the past years a new approach to sanitation has been introduced to prevent pollution and to recycle the nutrients of human excretions. This is an ecological approach where water use is minimal or negligible beside a slight or no release of wastewater. According to Werner et al [18] Ecological Sanitation doesn't favour a specific technology. It contributes a philosophy that recognizes human excreta and water from the household as a resource and not as waste, which should be available for reuse. Thus, human waste is reused and the nutrients are recycled back into the soil, forming a closed loop system (Figure 3.3) as opposed to the conventional system (Figure 3.1), where the nutrients are wasted and not used for agricultural purposes. The advantages of EcoSan can be summarised as follows [19]:

- EcoSan improves health by minimising the introduction of pathogens from human excreta into the water cycle.
- EcoSan promotes a safe and hygienic recycling to use valuable nutrients in human excreta.

- EcoSan conserves the natural sources by reducing water consumption, substitution of chemical fertilizers and minimises the water pollution.
- EcoSan prefers modular, decentralised, separated flow systems for more appropriate and cost-effective solution.
- EcoSan helps to preserve soil fertility by hindering the steady loss of nutrients and organic matter.
- EcoSan improves agricultural productivity and contributes food security.
- EcoSan promotes a holistic and interdisciplinary approach.

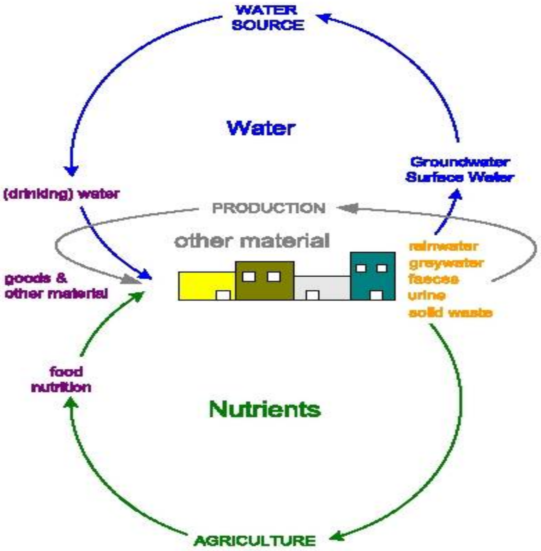


Figure 3.3.: Circular flow in an EcoSan system. [18]

Returning nutrients from human waste to the soil however is not a new practice. Human waste has been used for thousands of years in China and since the 12th century in Japan. [15] But there are also European countries like Sweden where such methods were implemented in the 18^{th} century. Today EcoSan applications such as the dry toilet and others are being used on every continent.

3.4 EcoSan applications

The brief paragraph below describes the functionality of two toilet systems. The dry toilet as illustrated in the figure 3.4 and the composting toilet.

In a dehydrating system the urine is separated from the faeces to keep the processing chamber contents dry, the volume of the material small and to prevent urine being polluted with excreta. This makes it possible to use the urine directly as fertiliser. Faeces fall into the processing chamber where they are stored for a period of 6-12 month, and ash, lime or dry soil is added after each defecation to lower the moisture and to raise the pH-values in view of destroying harmful pathogens.

In a composting toilet human faeces, either with urine or not, are stored in a processing chamber together with organic household and garden refuse and other agents like straw, peat moss, wood shavings etc. Various organism convert the solid into humus several conditions, like temperature, airflow, moisture etc, have to be controlled to contribute an adequate decomposition. After a period of approximately 6-8 month the partly decomposed material can be removed and used for secondary treatment. [15]

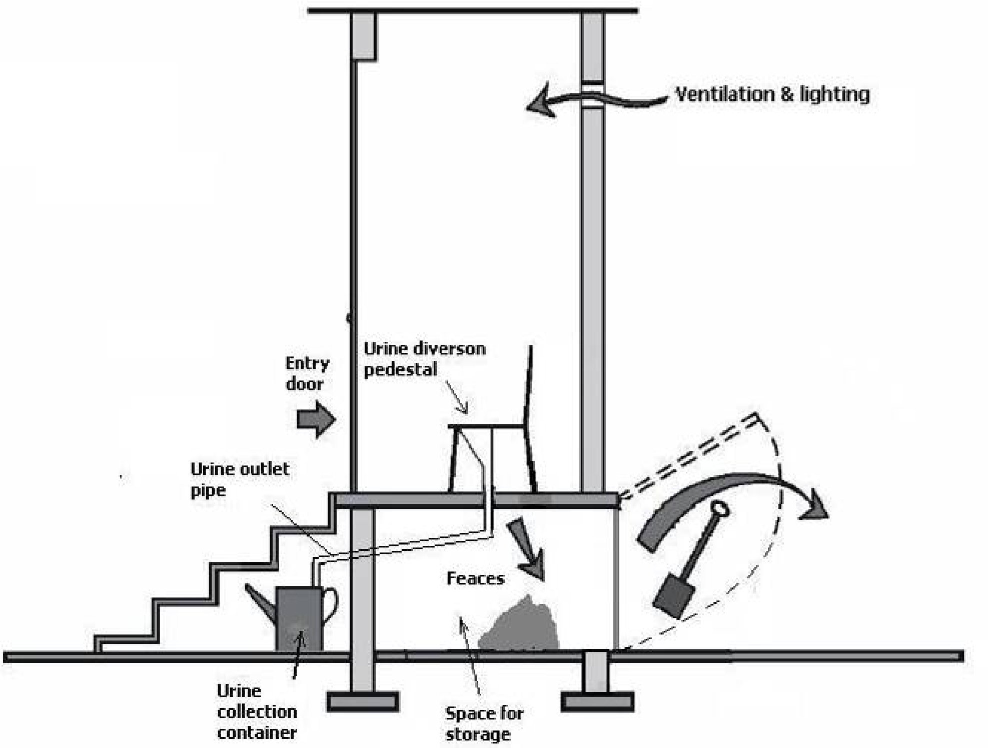


Figure 3.4.: The main principles of an elevated dehydrating toilet.[16]

As it is shown in figure 3.4 the dry toilet is based on a simple but effective technical concept. From this point of view it might appear unsuitable to talk about a rectification of present ventilation practices, as European aeration techniques are merely connected to cost intensive and complex installations. But it is clear that there has to be a continual improvement (further development) on these purviews in order to be an option to water borne sanitation systems. Ventilation standards should not, therefore, be regarded as immutable.

4 Theoretical fundamentals

4.1 Ventilation criteria

4.1.1 Remark

At this moment it's not aimed to apply European standards, concerning the purviews of ventilation techniques, in all its complexness, on dry toilets. All following basic knowledge (chapter 4) is based on national or European wide research. Therefore it should be seen as a support for further deliberations and further adaptations.

An implementation, especially of electronic devices, without consideration of underlying parameter would cause an enormous financial and technical effort and would therefore disagree in many aspects economical, ecological and technical deliberations. The parameter to consider can be summarized as follows:

- Electrical infrastructure (availability, supply)
- Technical infrastructure (operation & maintenance, sustainability, availability of technical devices)
- Construction outlay (purchase price, erection costs)
- Operating costs
- Environmental impact (pollution, noise,…)
- Cultural & social acceptance

Ventilation standards should be simple in concept and presentation, and should include a statement of the objectives in chapter 1.3, both to permit more effective updating in the light of new knowledge and to allow intelligent applications by the user.

4.1.2 Development of ventilation systems

The development of active ventilation techniques for living - and working spaces is a major human concern since the construction of stationary and closed buildings. The Ventilation systems of the Roman or the Hellenistic empires worked on the physical principle of natural ventilation. The aim of these constructed schemes was not to dilute or replace used air. It was rather an equable lift of the warm air layers due to the inlet of warm air near the floor.[20]

From the antique up to the Middle Ages only little improvements were achieved. The ventilation schemes still worked on the principle of natural ventilation. The big spaces of ancient churches and castles were all erected under the consideration, that the required air was able to refill the space on natural way.

Only since the end of the 18th century, the beginning of the industrialisation, scientists have been focussing on that complex of themes. Especially production workshops, hospitals and theatres, with a high occurrence of contaminated and heated air, created a demand on improved ventilation.

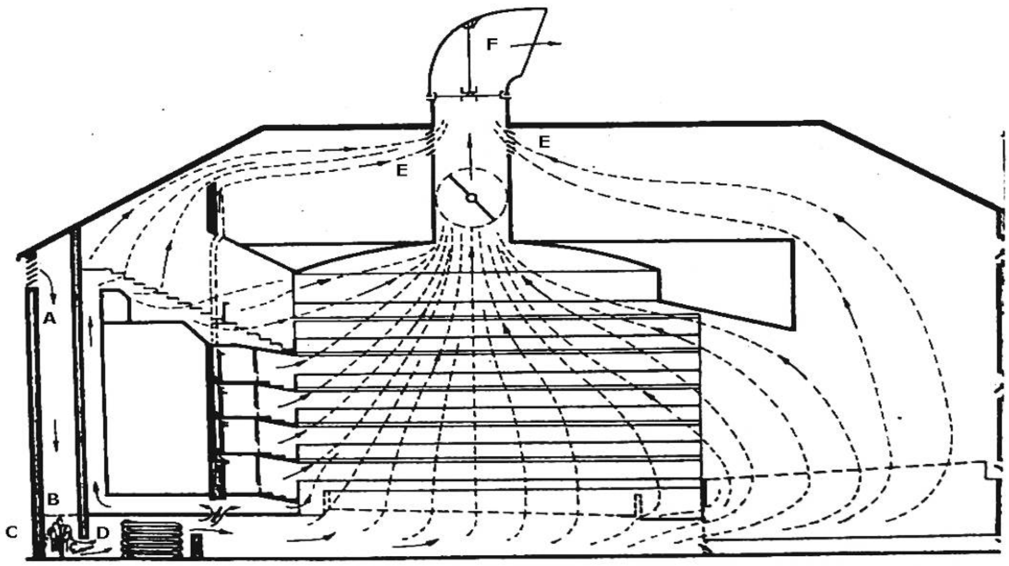


Figure 4.1.: Ventilation of a theatre after Reid (1844) [21] A – Supply air; B - air filtration; C – humidifying; D – heating; E – exhaust air; F – turn able fan outlet

Engineers realised quit fast the insufficiency of natural ventilation in that connection. Therefore the need to improve the new event locations and to meet the steady increasing standard of living was obvious. Hence, in the second half of the 19.century studies on mechanical forced ventilation were carried out. One of the first expedient mechanical systems was transcribed at the London Parliament Building from 1845 to 1847.

4.1.3 Tasks and specification of indoor ventilation

The main task of air handling systems is the renewal of used inside air, if necessary with further air treatment. It should create an indoor climate which is able to satisfy human demands. The term indoor-climate covers the items thermal climate and indoor air quality. Whereas the thermal climate describes all parameter with an influence on the human heat balance (air temp.; surface temp.; air movement and many more) and the indoor air quality (odour; pollution..) describes all other air parameter with an effect on humans. [22]

The European Committee for Standardization also defines, in its CEN Report CR 1752 (Ventilation for buildings – Design criteria for the indoor), acoustics as a third major attribute influencing the indoor climate.

Riccabona [23] describes the two main reasons for air renewal as follows:

- Contaminated indoor air should be diluted or replaced by fresh air in order to remove all harmful and disturbing pollutants. Indoor air neither should annoy people nor disturb working processes.

- It should be possible to sustain a comfortable room temperature and humidity. If this cannot be reached due to heating systems the fed air must be prepared according to the situation.

It appears logical, that different persons have a distinguish impression of one specific indoor climate. But extensive research activities, under the same trial conditions, have shown that the judgement of man and woman respectively young and old nearly doesn't deviate. That means sex and age must not be taken into account by determining the design criteria. But it demonstrated that parameters like the activity – grade, health condition and others have a high impact on the comfort.[24]

Table 4.1.: Influence magnitudes on comfort according to Frank.

Influence of humans	Influence of the room and the air-handling system or heating system
Grade of activity	Air temperature
Clothes	Temp. of the surrounding surface
(Age)	Air velocity
(Sex)	Air humidity
Health condition	Noises
Length of stay	Illumination
Room occupation	Room-colour
Adaptation	Shape and size of the room
Acclimatization	View
Rhythm of the day	Air renewal
Rhythm of the year	Air quality
Ethnical influences	Air pressure
Social-physical situation (working climate)	Odour

These previous mentioned influence magnitudes (table 4.1) have to be coordinated in order to model an optimized climate, which is able to meet the demands of the user. An ideal combination hardly can be reached in reality. Therefore it's quit important to know how far the practical values can deviate from the ideal conditions. A concept on how to handle this question was developed by Ole Fanger and entered the international standardisation guidelines (ISO 7730).

4.1.4 Air pollution

The amount of air pollution mainly depends on the usage of the specific room and is highly affected due to human activity, electronic and mechanical devices and external environmental conditions. Regarding the dry toilet, the sources of air contamination are the feaces, stored beneath the user chamber and the urine odour expelled by the urine pipe.

Air pollutants can be [17]:

- Odour: Limiting values of odour nearly doesn't exist. The measurement of the concentration is often because of the low odour-sill impossible. Especially in view of this problem the necessary external air-exchange-rate are in many cases specified via the room application. =>Air exchange rate [1/h] (see air – requirement, chapter 4.1.5)

Table 4.2.: Sill-values for odour in ppm (part per million) [24]

Odour	Odour-sill	Odour	Odor-sill
Acetone	450	Pyridine***)	0,23
Benzoic	300	Formaldehyde*)	0,2
Ammoniac	53	Schwefelwasserstoff	0,18
Chloe	3,5	Ozone	0,05
Schwefeldioxid	3,0	Buttersäure	0,000065
Amylacetat**)	1,0	Artificial Moschus	0,0000034
*)appers at the production of synthetic material			
**)Varnish-solvent			
***)for example tobacco			

- Heat output: The heat output of one human being is about 100W (Watt), under calm working conditions, and can be increased due to physical work up to 700W.

Table 4.3.: Heat output according to the grade of activity.

Physical activity	Grade of activity	Heat output/person [W]
little	calm sitting (reading, writing)	100
	light phy. act. while sitting (paperwork)	120
normal	light phy. act. while standing (barber)	150
	medium physical activity	200
strong	hard physical activity	300
	heaviest physical activity	up to 700

- Steam (water vapour): The steam output of one human being is about 46 g/h at a temperature of 22°C. That means, 10 persons emit, during the period of two hours, about 1 litre of water into the air.
- Carbon dioxide (CO_2, CO): Max von Pettenkoffer (1819-1901) defined the Human being as the main source of air contamination and declared Carbon Dioxide as the main indicator for indoor air quality. Therefore the rate of air-exchange was depending on the number of persons. =>Supply air rate [m^3/h] (see air exchange rate)
- Bacteria, viruses (hospitals)
- Allergens
- Particle, fibres (smoke, textile-fibres...)

- Radon: It occurs in air, floors and building materials and deposits on dust particles.

Pollutants can either appear in terms of gas or dust. Air contamination causes, beside the disturbance of odour, serious health damage. For this reason a maximum working place concentration (MAK indexes) have been introduced in 1979. In general they are valid over an average period of one working day (~8 hours) respectively one working week of about 45 hours.

MAK-indexes are only based on the aspect of health, not on the aspect of odour. A combination of specific pollutants can cause a stricter regulation.

MAK-indexes are given in:

- [cm^3/m^3] ppm (parts per million) for gases and steam and
- [mg/m^3] for smoke, particles...

4.1.5 Air requirements

4.1.5.1 General deliberations

The odour sources in dry toilets are separated. Faeces are located in the processing chamber underneath the user room, while the source of urine odour is located at the bottom of the user chamber, expelled by the urine pipe. Hence it is aimed to generate a low pressure area within the processing chamber, to generate an air flow from the user chamber towards it.

The amount of air, that either has to be lead away or fed, highly depends on the specific ventilation method and the main demands of the different implementations. In view of the dry toilet, the main ventilation construction criteria are the generated amount of odour emitted by a pile of faeces, the urine emitted by the urine pipe, the generated amount of odour emitted during the defecation process, the place of storage and various economical and ecological deliberations. To determine required air volume-streams, various calculation methods are mentioned below. In the case of free ventilation, with its unsteady volume streams due to changeable weather conditions, such as winds and solar radiation, it’s hardly possible to fulfil the underlying supply air rates continuously over a period of one day. Therefore, interactions of various constructions and implementations have to be taken into consideration. For example a flow accelerator on top of the vent pipe, a mechanical squatting pan lid beside an intelligent air guidance concept and many more. Various supply air rates according to specific demands are listed below:

1) the determination in dependence on physical activity
2) the determination according to air-exchange rates
3) the determination according to air pollution (MAK-values)
4) the determination according to norms and regulations

5) the determination according to the heat load
6) the determination according to the cooling load
7) the determination according to humidity

Number 5, 6 and 7 are only of interest in connection with an air handling system. Therefore they will not be further discussed.

4.1.5.1.1 The determination in dependence on physical activity

The basis for this calculation is the Carbon Dioxide (CO_2) production of a human being in dependence on his physical activity. Assuming that the external concentration accounts 350 ppm (parts per million) as well as a maximum acceptable concentration of 1000 ppm (according to MAK - values) following demands can be specified.

Table 4.4.: Volume streams according to the ÖNORM H 6000 T3

			Entire heat output (physical activity) in Watt				
			100	120	150	200	300
Non smoking rooms	$V_{AUL,min}$ per Person	in l/s	6	8	10	13	20
		in m³/h	~20	~30	~35	~45	~70

4.1.5.1.2 The determination according to air-exchange rates

This air –exchange rates refer to experienced values and depend on the room-dedication. The product of the exchange rates and the room area determine the amount of air, which has to be expelled. In this case various values are available, whereas the worst case has to be considered.

$$\dot{V}_{Waste} = n \cdot V \qquad (4.1)$$

$\dot{V}_{Waste}$ Waste air volume stream [m³/h]

n..... Air exchange rate [1/h]

V .... Volume of the room [m³]

Table 4.5.: Experience-values of various sources

Room – dedication	Air exchange per hour	Source
WC in a flat	4-5	Heliosventilatoren [25]
WC (public, trade)	5-15	
WC	10-15	Klima – Studienblätter [26]

4.1.5.1.3 The determination according to air pollution (MAK-values)

The MAK values define the maximum concentration of pollutants in a working place or a lounge area. Some values are given in Table 4.2, chapter 4.1.4 "Air pollution". The calculation is described below.

$$\dot{V}_{Waste} = \frac{K}{k_i - k_e} \qquad (4.2)$$

$\dot{V}_{Waste}$ Waste air volume stream [m³/h]

K .... Accruing pollution [cm³/h]

k_i .... Maximum inside concentration > MAK value in ppm

k_e.... External concentration of the supply air in ppm

4.1.5.1.4 The determination according to norms and regulations

According to the regulation ÖNORM M 7636 "Ventilation for residential zones in buildings", the a basic ventilation for a WC should be 0,4 m³/h per m² flat area and the operating ventilation about 50 m³/h. Other regulations are mentioned in table 4.6.

Table 4.6.: Volume streams respectively air exchange rates in WCs according to various regulations

Type of room	Waste air volume streams rather exchange rates according to					
	DIN 18017 [27]	VDI 2088 [28]	DIN 1946 [29]	SBN [30]	V.M.C. [31]	NEN [32]
WC	30 m³/h	30 m³/h	20 m³/h	30 m³/h	30 m³/h	25 m³/h

4.2 Ventilation systems

This digest describes, very briefly, various types of ventilation systems for houses and its rooms and their effect on the air pressure and the operation of other appliances. Further and more detailed information can be taken from the standardisation Norm DIN 18017 part 1 "Ventilation of bathrooms and WCs without outside windows and ventilators", part 2 " Ventilation of bathrooms and WCs without outside windows by fans" and other information sources posted in chapter 9 "References".

4.2.1 Free ventilation

4.2.1.1 Fugue aeration (joint ventilation)

This type is also called random ventilation because the air exchange happens more or less accidentally

The air exchange is caused by leakages of the surrounding surface, especially of windows and doors. Basic assumptions are a pressure-difference between the indoor– and outdoor area. (Depend on thermal differences and wind accumulation) The amount of air exchange primary depends on the size of the joints, weather conditions and wind velocity. [23]

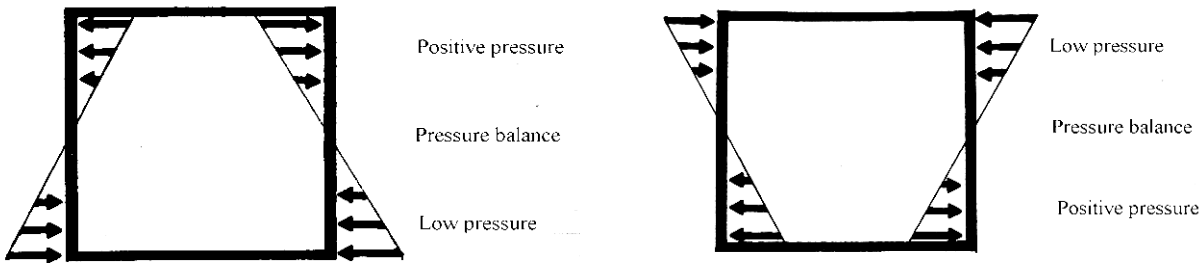


Figure 4.2.: Air flow due to temperature (pressure) differences.

The distribution of odours, especially of the kitchen and the toilet, is a main problem and has to be taken into account by planning a non-electrical system.

If it is aimed to ventilate the kitchen, toilet and the bath due to a window or a joint aeration also the wind direction and its strength have to be taken into consideration. Figure 4.3 illustrates a ground floor of terraced houses. The wind, moving as indicated, causes even with closed windows an uncontrolled distribution of kitchen and toilet odours. Open windows accelerate this process.

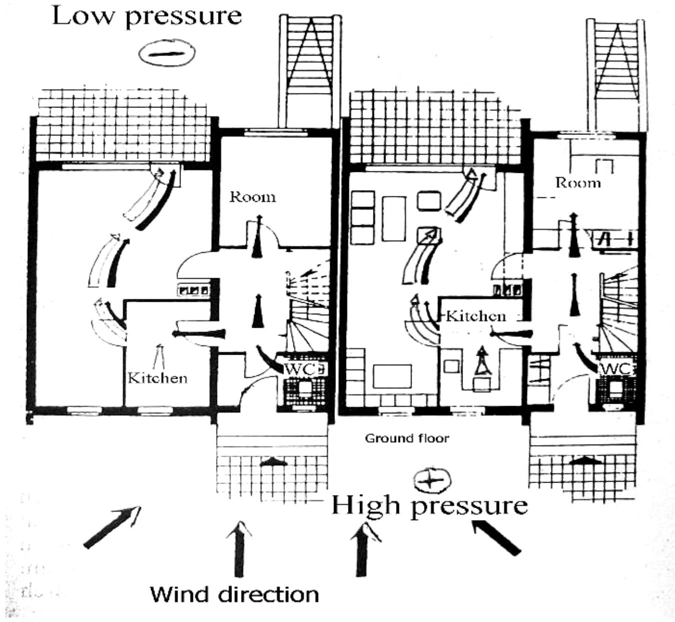


Figure 4.3.: Odour distribution due to wind. [33]

4.2.1.2 Window ventilation

The functionality is based on the same physical substructure as the joint ventilation, mentioned above. Therefore, the applications of small and high windows appear more useful than of low and broad. Suitable are sliding windows and swing casements, because their equal inlet– and outlet area benefits an adequate aeration.

Especially in winter, skylight windows, near the ceiling, contribute to a reduction of an odour distribution. As you can see in Figure 4.4, picture D, used (warm) air is carried away, due to the thermal ratio of indoor– and outdoor temperature, through the window and replaced by fresh air entering through joints of the door or the window. Thus, a negative pressure occurs in the particular room.

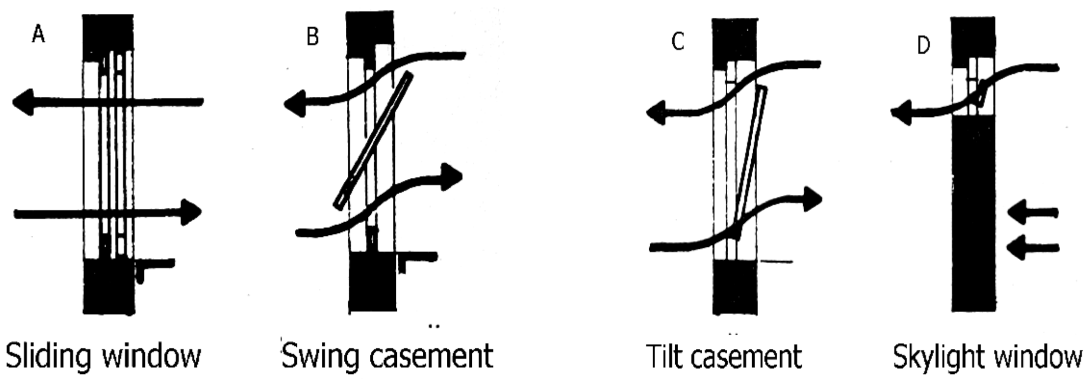


Figure 4.4.: Variations of window ventilation.

4.2.1.3 Thermal Duct ventilation

The thermal duct ventilation works due to outdoor and indoor temperature differences. Therefore, a vertical movement upwards is only possible if the indoor air temperature is higher compared with the ambient temperature. An inverted temperature ratio would be counterproductive and would cause a downward stream. As it is shown in Figure 4.5, in dependence of the temperature difference and the effective duct height a certain amount of waste air can be lead off.

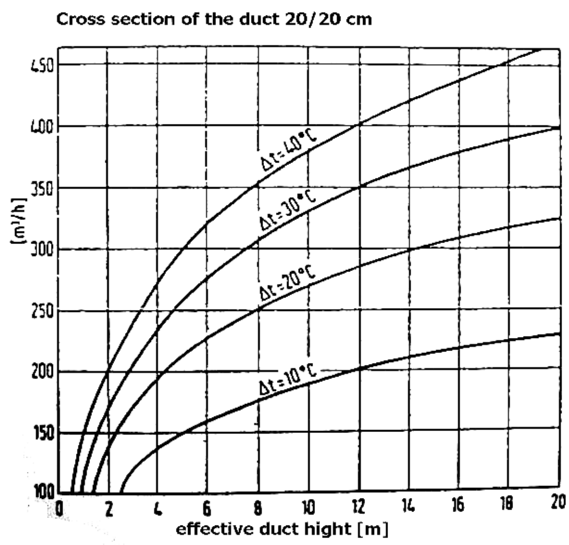


Figure 4.5.: Waste air stream [m³/h] due to temperature difference and effective duct height. [23]

To maintain an air flow, all rooms being ventilated need supply air either due to supply air ducts or joints of windows respectively doors. To avoid the construction of supply air ducts, with the burden of further investments, joints have to ensure a sufficient supply rate. This can be achieved, for example, through supply air grilles at the bottom of doors.

According to the DIN 18017 "Lüftung von Bädern und Toilettenräumen ohne Aussenfenster – Ventilation of bathrooms and WCs without outside windows" all rooms without windows need supply air ducts and should consider following guidelines:

Table 4.7.: Extract of the norm DIN 18017

Definition	Dimensions, others
Waste air ducts	Cross-section >=140cm²; Seize and shape shouldn't change along the whole length.
Waste air openings	Cross-section >=150cm²; placed near the ceiling
Supply air ducts	Cross-section >=80% of all connected room supply air ducts
Supply air openings	Cross-section >=150cm²; placed near the floor

Furthermore, waste air ducts need to be 1,0m above the roof surface and 0,4m above the ridge, if it appears near to it. They also should be 0,4m taller than barriers.

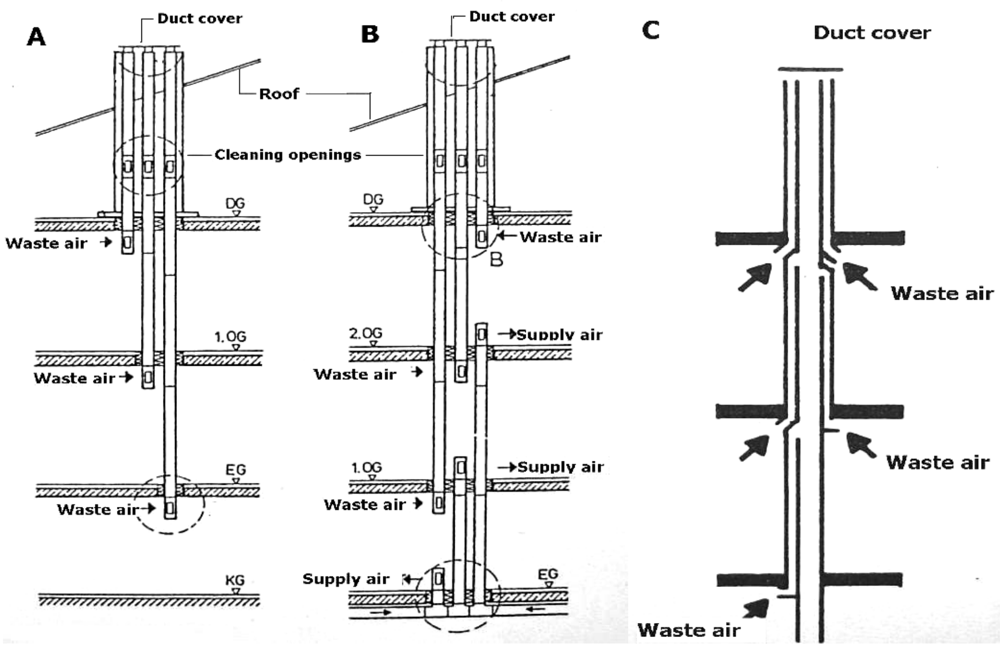


Figure 4.6.: Various schematic methods of duct ventilation.

Image A shows a single duct ventilation without supply air ducts. Single duct ventilation means that every single duct is only used for one specific room. Image B indicates a single duct ventilation with supply air ducts. Image C represents a collection duct ventilation. This type is cheaper than the single duct ventilation but more susceptible to an acoustic transfer.

4.2.2 Mechanical ventilation

Adequate ventilation is essential in all houses to ensure acceptable indoor air quality, control condensation, and in some cases to ensure sufficient supply of combustion air for fuel-fired heating appliances. In the past, most houses were ventilated by air leakage through cracks and openings in the building envelope, but in recent years the desire to conserve energy has led to tighter house constructions and the upgrading of existing standards. This has been sometimes so successful that air leakage can no longer be relied upon as the sole source of ventilation air. As a result, mechanical ventilation system are often been added to meet the recommended rates and to generate a directed air flow.

4.2.2.1 Exhaust-only ventilation system

The exhaust only system uses an exhaust fan to expel indoor air to the outdoor, thereby lowering the air pressure inside the house so that outdoor air is drawn in through cracks and openings of the building envelope.

To prevent an odour annoyance of the surrounding areas it is advised to dispose waste air only above the roof.

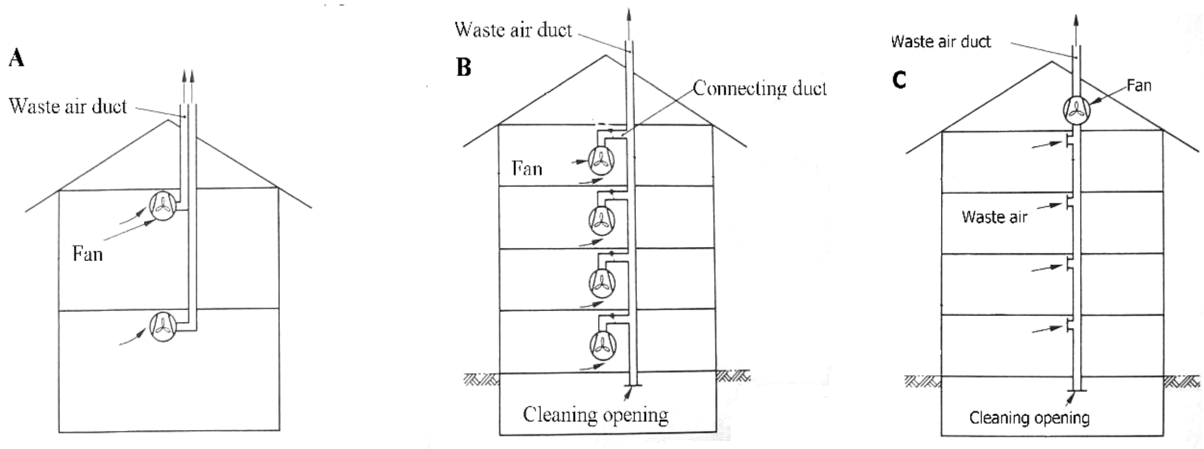


Figure 4.7.: Schemes of Exhaust only ventilation system.[33] A) Single exhaust only ventilation system with separated waste ducts. B) Single exhaust only ventilation system with common waste air duct. C) Central exhaust only ventilation system with a common changeable volume flow

Single exhaust-only ventilation systems are installations with fans for each connected flat or room. It allows an individual usage of the ventilating system which is able to meet the demands of the occupants. The fans can be activated for example due to an own switch or in connection with a light switch. Therefore the electricity consumption is quit low.

Central exhaust-only ventilation systems are installations with one common fan for several flats or rooms. The system with common changeable volume flow allows no individual adjustment. Every flat has to cope with the same volume flow. Further applications are the "Central exhaust-only ventilation system with individual changeable volume flow" due to adjustable waste air openings, and "Central exhaust-only ventilation system with steady volume flow" independent of the pressure ratio of the system and the ventilated room due to special waste air openings.

4.2.2.2 Supply only ventilation system

A supply-only system relies on a supply fan to bring outdoor air into a house, raising the air pressure inside the house and increasing the outward flow through cracks and openings in the building envelope. Heat recovery is not possible with this system.

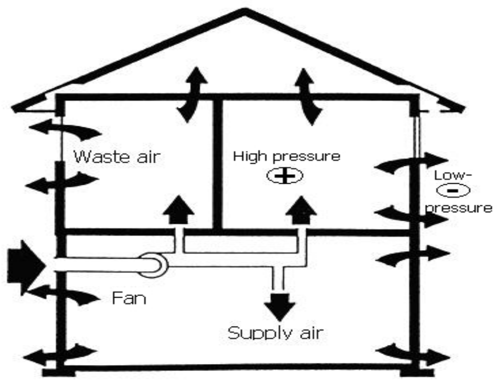


Figure 4.8.: Schema of a Supply-only ventilation system.[34]

To avoid disturbing air flow appearance by changeable outside air temperatures the supply air should either be warmed up or chilled. As it is illustrated in 5.2.1 "Exhaust only ventilation system" similar air flow principles can be transcribed to this system.

4.2.2.3 Balanced ventilation systems

A balanced system draws outdoor air into the house and expels an approximately equal amount of indoor air to the outdoors.

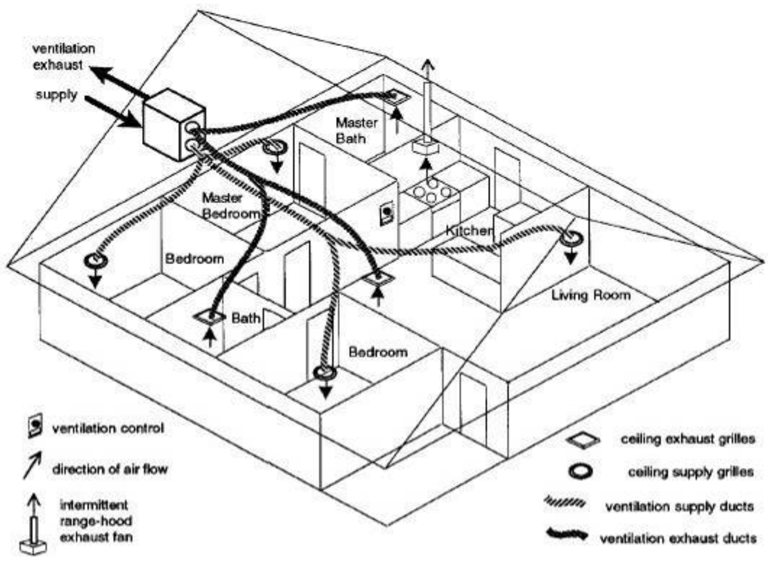


Figure 4.9.: Balanced ventilation schematic.[35]

Figure 4.9 shows a balanced ventilation system in a small home. Fresh air enters the home through a single intake and is distributed through ducts to the living and sleeping areas. Used air is removed from the home through a separate exhaust duct with inlets, typically located in bathrooms or toilets. The kitchen has a separate, manually operated exhaust fan located in the range hood. These systems can operate continuously or only when the house is occupied. The supply and exhaust fans are equal in capacity to maintain indoor pressure balance.

In severe climates, balanced ventilation systems can be equipped with a heat exchanger that recovers most of the heating and cooling energy from the exhaust air.

4.3 Aerial guidance principles

The selection of the right aerial guidance is depending of the usage, the geometry and shaping of a room, the demanding supply air and external air mass-flows, the required room air parameters and the integration into urban and rural landscape concepts.

All this points have to be considered by planning a ventilation- and climate concept. That means they are not only valid for living and working places but also for technological processes, animal keeping sites, hospitals, shopping malls and warehouses.

Only with a clear requirement profile it is useful to deliberate about suitable air handling concepts in view of energy economical aspects, relevant comfort criterions and the aerial guidance. There are no fixed regulations in this connection, because it’s neither possible nor necessary to consider all facial-points. It’s more important to search for realizable compromises. [36]

General distinction of aerial guidance principles:

- Mix aeration
- Displacement aeration
- Source aeration

4.3.1 Mixed aeration

This ventilation method is wide spread. Air enters in form of free-rays, with a high impulse, and causes a mixing of fresh air with used air. The free-rays mainly enter the room from the side wall and in ceiling level. But they can also move, in dependence on the position of the entering devices, from the bottom of a room to the top and the other way around. Within big rooms also a local mixing can be transcribed. Local mixing distinguishes itself by small rays with less impulse but a high level of turbulence. (See figure 4.10)

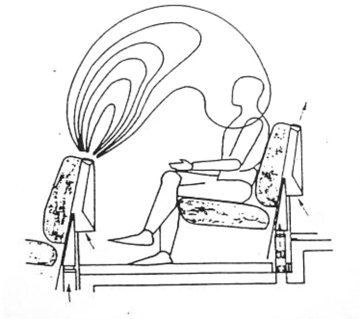


Figure 4.10.: Local restricted mixture of supply- and used-air

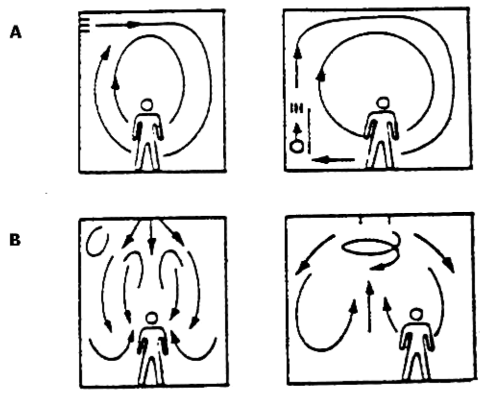


Figure 4.11.: Various entering methods. A) Tangential aerial guidance. B) Diffuse aerial guidance

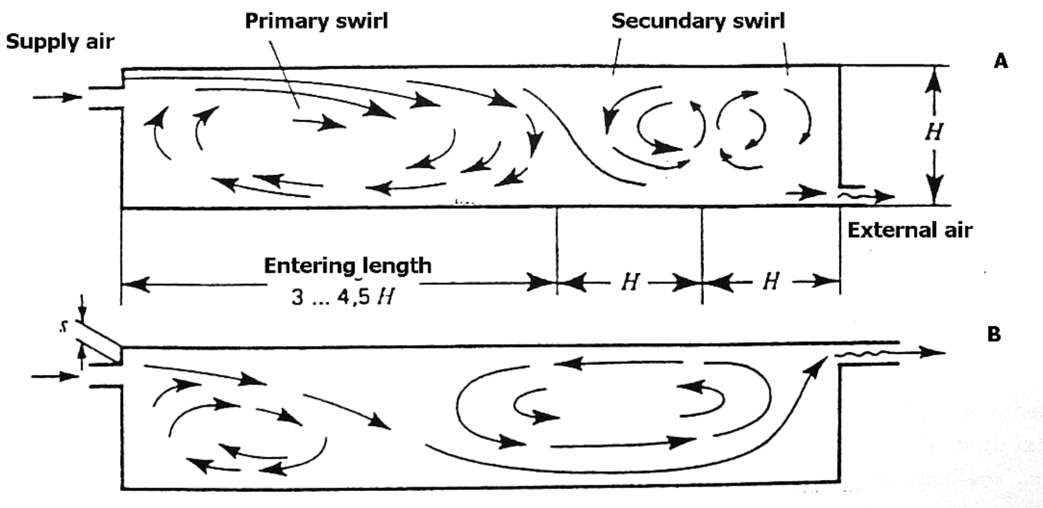


Figure 4.12.: Air flow images. A) Isothermal or warm air-ray. B) Cold air-ray

4.3.2 Displacement aeration

Displacement aeration is applied to places where the mixing of fresh and used air is not desirable. For example surgery rooms, laboratories, industries and many more. Ideally the supply air enters through extensive areas the room and is carried off from its opposite side. The room reacts in this case like a section of an air-channel.

Due to the displacement aeration it should be possible to prevent contaminated air to be distributed. The best results are achieved with a relatively steady and regular air flow. This can be best achieved due to the usage of a bunch of small free-rays with a low turbulence level. In practice it's hard to fulfil these demands because even small interruptions due to barricades or heat outputs cause a mixing.

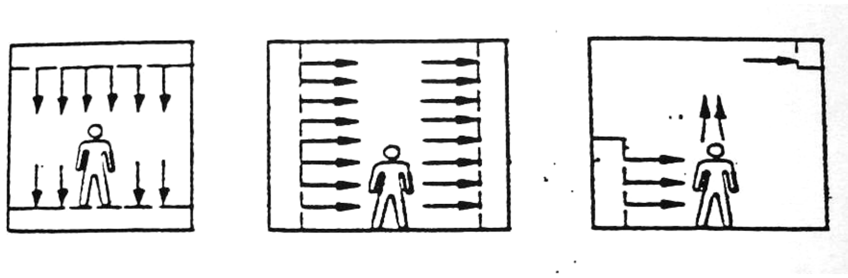


Figure 4.13.: Various entering methods

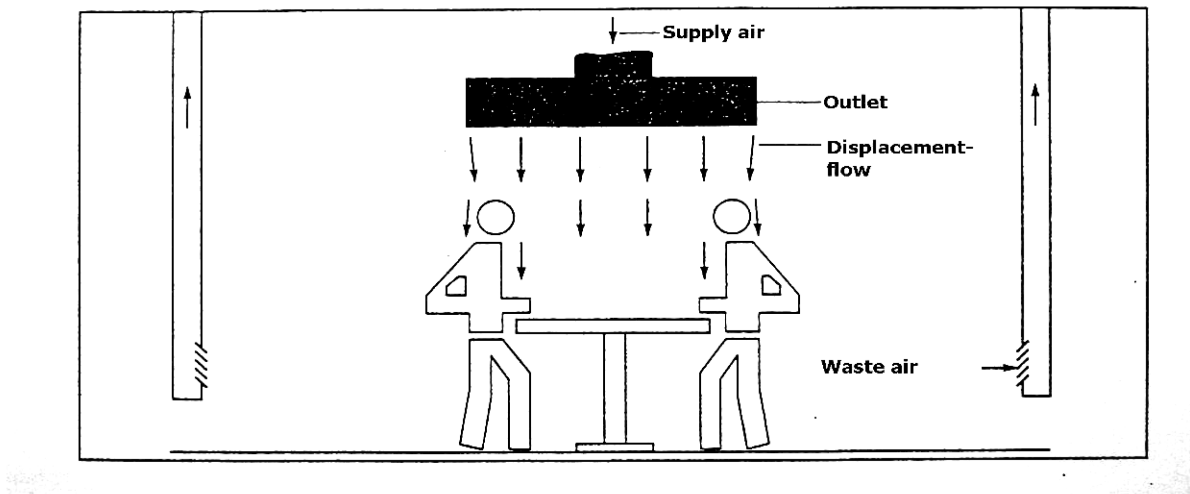


Figure 4.14.: Displacement aeration at a working station

4.3.3 Source aeration

Principally the source aeration is a special form of the displacement aeration. It's force is bottom up directed. At this, the buoyancy of heat sources is a substantial transport mechanism to lift used air towards the waste air openings.

The aim of this method is to ventilate only the used part of the room. In most cases it is the lower area, with an average height of about 1.80 m. For this reason cold air is brought in at ground level. To prohibit a room-filling air-stream, the air-input velocity has to be very low. Two separated room streams are achieved on this principle. One stream has a high level of turbulence and one a low level of turbulence.

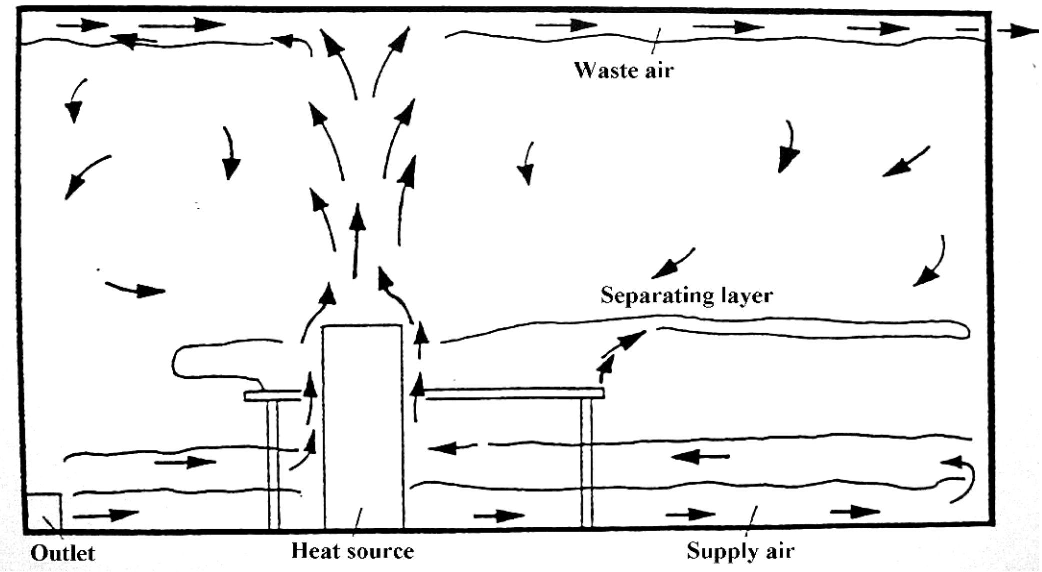


Figure 4.15.: Flow illustration of a source aeration

The aware generation of two horizontal separated air-zones requires a slight air input. That means the air velocity should be not higher than 0,2 – 0,4 m/s and the temperature difference between supply –and room air not more than 4 K.[36] In the case of big cooling loads, the combination of these two demands cause high supply air amounts and therefore high outlet areas.

4.3.4 Free ventilation

In most cases the free ventilation is an effective and energy economical technique to meet specific room air requirements.

The area is flowed through due to differences of pressure, which adjust themselves between the area and the atmosphere. The differences of pressure are a consequence of temperature differences, density variations, wind pressures and pressure losses at the openings along a flow path. With sufficient thermal buoyancy no additional flow drive is needed.

Space conditions such as temperature, dampness, pollution level and so on depend at this system mainly on the outside air conditions.

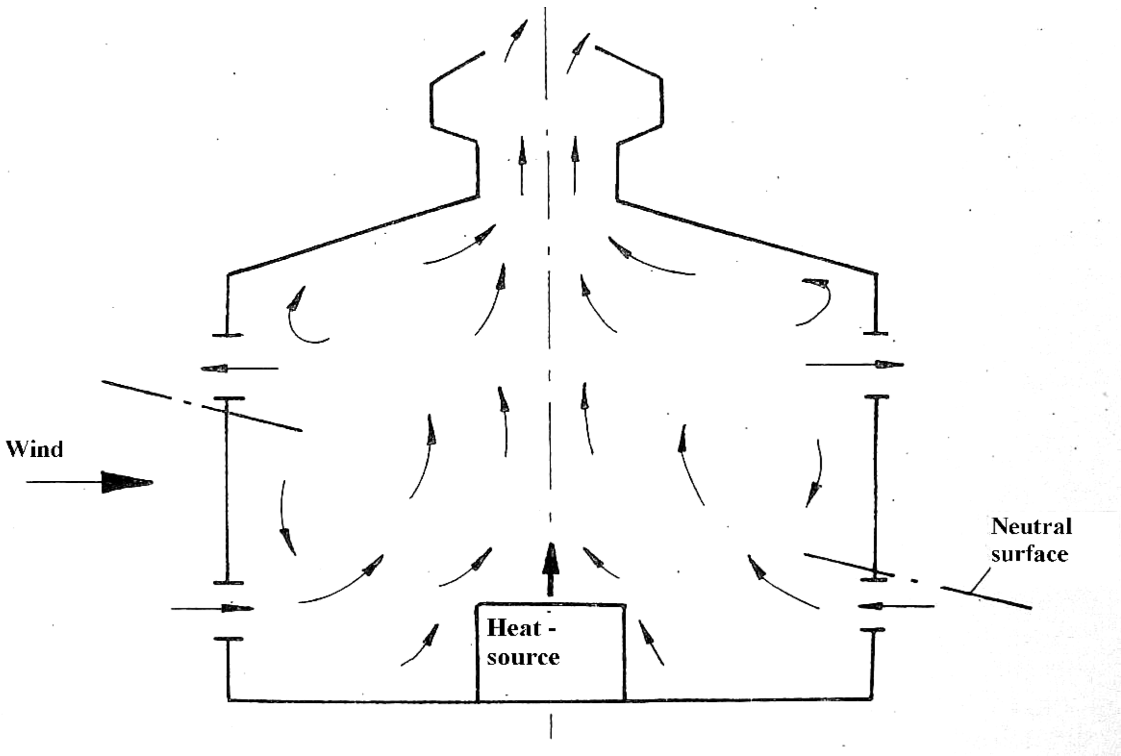


Figure 4.16.: Flow image of a free ventilation [36]

Illustration 4.16 shows the schematic representation of free ventilation in an enterprise with a heat output. Beside the inner load, the wind pressure highly influences the flow image. As you can see in figure 4.16, if wind pressure is increased, the neutral area would turn clockwise. In that case, wind would also enter trough the upper opening and carried off through both opposite openings. The neutral area would be horizontal in the case of calm wind conditions.

Openings above the neutral area are called outlets and openings underneath are indicated as inlets. The further openings remote from the neutral surface, the more higher is the supply air speed. By opening and shooting of inlets and outlets it is possible to change pressure ratios and change thus the situation of the neutral surface.

The outlined principle in Figure 4.17 is valid for the flow through large halls, but also for the free ventilation of a room with a window. If you assume, that the room is tight and wind pressure is constant, the neutral surface is vaguely situated in the middle of the window. As a consequence and in reliance of the ratio between indoor –and external temperature, air is entering respectively carried off below the neutral surface and conversely.

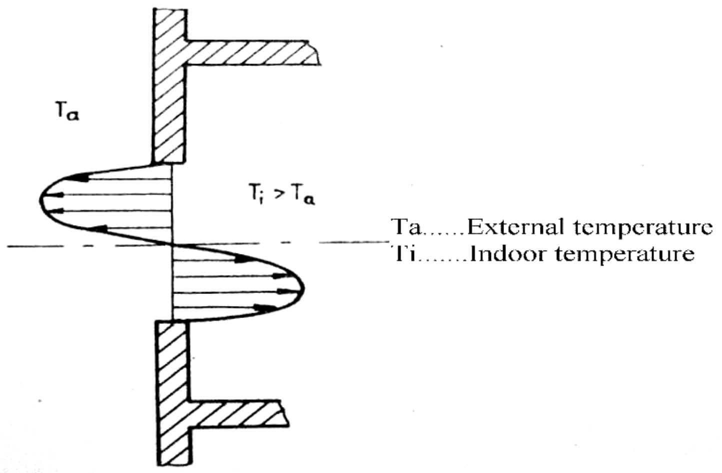


Figure 4.17.: Velocity profile of an open window

4.4 Air-duct dimensioning

The prime costs and the function of a ventilation system mainly depend on the pipeline construction. Higher velocities beside smaller diameters imply less system costs, yet the increasing pressure loss causes higher operating costs at mechanical ventilated facilities. According to physical fundamentals the pressure loss is changing with the quadrate of the velocity. Therefore a high air velocity, due to small diameters, could cause a ventilation breakdown, if the air is not able the overcome the likewise increased friction resistance.

Especially at a free ventilation system it is aimed to reduce air resistances, caused by pipe friction, shaped pieces and installations, because in this case forces to generate an air movement are not continuous, since they depend on winds on temperature differences. [37]

4.4.1 Stream equation

The stream equation represents the relation between the,

- air volume stream,
- the air duct cross-section and
- the stream velocity

$$\dot{V} = A \cdot w \tag{4.1}$$

$\dot{V}$ ... Air volume stream [m³/s]

A .... Air duct cross section [m²]

w .... Stream velocity [m/s]

4.4.2 External pressure loss

The external pressure loss describes the pressure loss in air channels. Responsible for this losses are the,

- Resistance due to friction (pipe-friction)
- Resistance due to shaped pieces (bows, T-peaces..)
- Resistance due to components (supply air openings..)

$$\Delta p_{ext} = \Delta p_R + \Delta p_z + \Delta p_E \qquad (4.2)$$

Δp_{ext} external pressure loss [Pa]

Δp_R … pressure loss due to friction [Pa]

Δp_Z … pressure loss due to shaped pieces [Pa]

Δp_E … pressure loss due to components [Pa]

4.4.2.1 Pressure loss due to friction

To deliver liquids or gases through a pipe, the driving pressure has to be greater than the pressure losses due to the surface of pipes.

$$\Delta p_R = \lambda \cdot \frac{l}{d} \cdot \frac{\rho}{2} \cdot w^2 \qquad (4.3)$$

Δp_R … pressure loss due to friction [Pa]

λ..... friction number[no dimension]; λ is a fkt. of the Reynolds-number

l...... length of the pipe [m]

ρ..... density [kg/m³]

d..... diameter of the pipe[m]

w.... middle velocity [m/s]

The pressure difference per meter pipe can also be expressed as the pressure-inclination R.

$$R = \frac{\lambda}{d} \cdot \frac{\rho}{2} \cdot w^2 \qquad => \qquad \Delta p_R = R \cdot l \qquad (4.4)$$

R .... pressure-inclination [Pa/m]

To calculate the the pressure inclination (R), the friction number (λ) has to be generated before.

$$\text{Re} = \frac{w \cdot d}{\upsilon} \qquad (4.5)$$

R_e ... Reynolds number [no dimension]

υ .... Kinematical viscosity [m²/s]

λ..... friction number [no dimension]

Table 4.8.: Kinematical viscosity of air at 1 bar pressure. [37]

t [°C]	0	20	40	60	80	100	200
$10^{-6} \cdot \upsilon$ [m²/s]	13,2	15,0	16,9	18,9	20,9	23,0	36,0

Due to the different flow ratings and their influence on the pressure inclination, it is to distinguish between a laminar and a turbulent flow. At the laminar movement the liquid particles move on parallel stream lines, in general with different velocities. At the turbulent flow the particles move, beside the main direction, also cross to it. The result of this multi-directed movement is a more even velocity profile. The value to distinguish between those two flow-ratings is expressed through the Reynolds number.

- Laminar flow => $R_e < 2320$
- Turbulent flow => $R_e > 2320$ (3000)

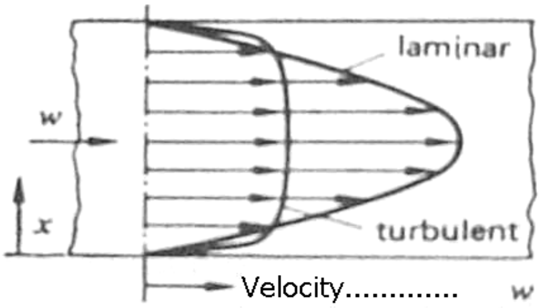


Figure 4.18.: Laminar and Turbulent flow.

The friction number and the consequential resulting pressure inclination for the laminar flow are personated below.

$$\lambda = \frac{64}{\text{R}_e} \qquad R = 32 \cdot \upsilon \cdot \rho \cdot \frac{w}{d^2} \qquad (4.6)$$

The friction number for the turbulent flow should be taken from the Figure 4.18, illustrated below. The application of this figure is more reliable than other calculation methods.

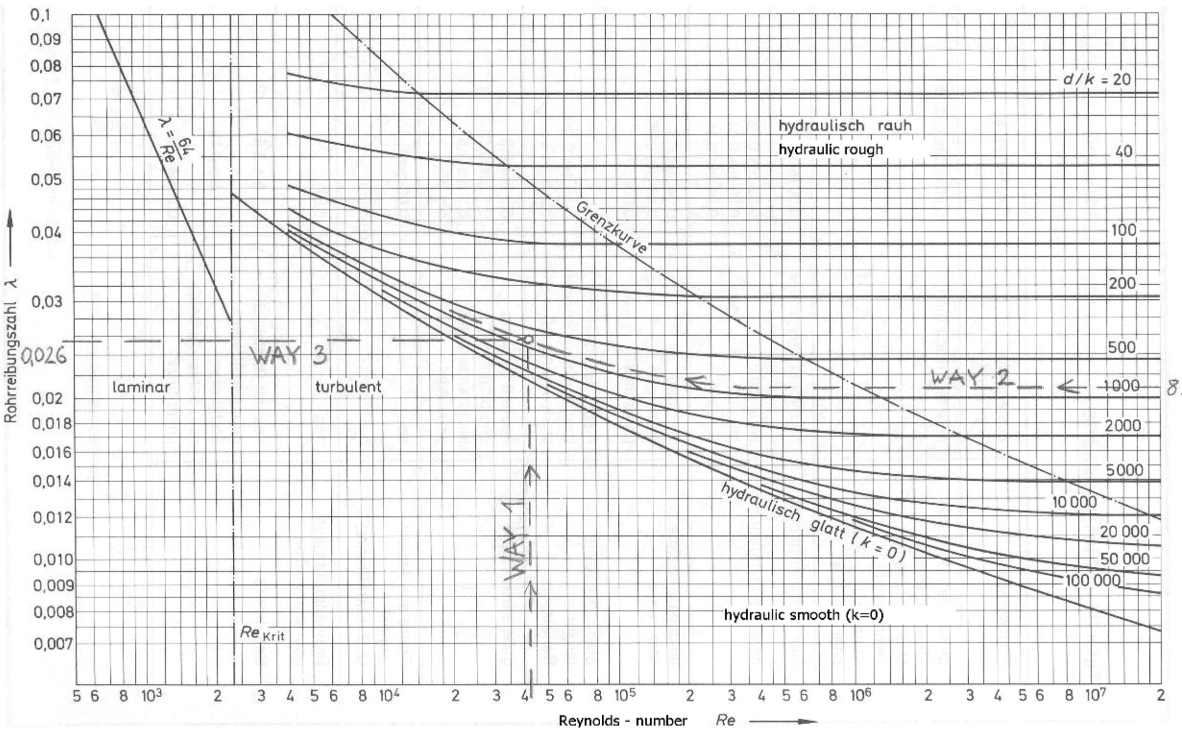


Figure 4.18.: Friction number λ [38]

Table 4.9 expresses the roughness of applied pipes and has to be taken into account by generating λ from the illustration above.

Table 4.9.: Roughness of different pipe-materials. [37]

Material of the pipe	Roughness k in mm
Emerged pipes	0,0015
PVC –und PE-pipes	0,007
Asbestos cement	0,05….0,1
Standard steel pipes	0,045
Galvanized steel pipes	0,15
Steel pipes, light rusted	0,15….0,1
Steel pipes, strong rusted	1,0…..3,0
Cast iron pipes	0,4…..0,6
Sheet metal ducts, folded	0,15
Flexible sleeving	0,6…0,8…..2,0
Rabitz, smooth	1,5
Wood ducts	0,2…1,0

Cement ducts, raw	1,0....3,0
Stonewalled duct	3,0....5,0

Example:

Given: A sheet metal pipe with a diameter (d) of 125mm, air velocity w= 5 m/s, air temperature t=20°C.

1st step: Determination of k= 0,15

2nd step: Determination of $\upsilon = 15{,}0 \cdot 10\wedge(-6)$ m²/s

3rd step: Determination or $\mathrm{R_e} = \frac{5 \cdot 0{,}125}{15{,}0 \cdot 10\wedge(-6)} = 4{,}2 \cdot 10\wedge 4$ => turbulent flow

4th step :Determination of λ with Figure 7.2, according to way 1-3 of figure 4.18. => λ= 0,026

5th step: Calculation of the pressure loss according to previous equation 7.3 or 7.4.

In the case of rectangular ducts a hydraulic diameter (d_H) has to replace the normal diameter.

$$d_H = \frac{2b \cdot h}{b + \mathrm{h}} \tag{4.7}$$

4.4.2.2 Pressure loss through resistances of shaped pieces

The size of the pressure loss of shaped pieces depends on

- the ζ-values (Figure 4.19) and
- the dynamic pressure

$$\Delta p_Z = \sum \zeta \cdot p_{dyn} \qquad p_{dyn} = \frac{\rho}{2} \cdot w^2 \tag{4.8}$$

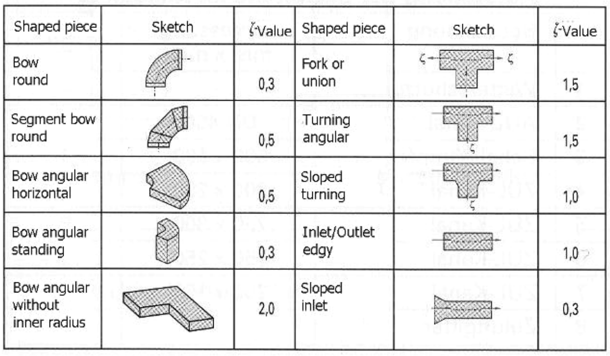
Δp_Z ...pressure loss due to shaped pieces

Σζ ... Sum of the resistances

p_{dyn} . dynamic pressure in Pa

ρ..... density of the air

w .... middle velocity [m/s]



Shaped piece	Sketch	ζ-Value	Shaped piece	Sketch	ζ-Value
Bow round		0,3	Fork or union		1,5
Segment bow round		0,5	Turning angular		1,5
Bow angular horizontal		0,5	Sloped turning		1,0
Bow angular standing		0,3	Inlet/Outlet edgy		1,0
Bow angular without inner radius		2,0	Sloped inlet		0,3

Figure 4.19.: ζ-values for different shapes [39]

4.4.2.3 Pressure loss through installations

Pressure losses can be caused by sound absorber, air openings, volume stream valves and other ventilation components. Various installation components and their pressure losses are stated below in table 4.10.

Table 4.10.: Resistances of various installations. [39]

Installation	Pressure loss Δp_E
Air outlet	10 – 50 Pa
Sound absorber	40 – 60 Pa
Butterfly valve	5 – 10 Pa
Volume stream valve - open	40 – 60 Pa
Fire damper	10 – 30 Pa

4.4.3 Thermal buoyancy and deviation

The thermal buoyancy increases according to the temperature difference between outside and inside and the difference of height between inlet and outlet openings. Another operative parameter represents the density of the air. It variances according to temperature and therefore generates different pressure conditions. The relation between density and pressure are briefly described through following equations (7.9).

$$\rho = 1{,}275 \cdot \frac{273{,}15}{(273{,}15 + t)} \quad => \quad \Delta p = (\rho_e - \rho_i) \cdot g \cdot h \qquad (4.9)$$

ρ..... density in kg/m³, ρ_e....external density, ρ_i....internal density

t ..... temperature in °CC

Δp... pressure difference in Pa

g..... gravity, 9,81m/s²

h..... height between inlet and outlet in m (meter)

Following example illustrates the impact of temperature differences on a so called shaft building. The floors of this building type are not air tight separated from each other. The connections are created due to staircases, elevator shafts and technical shafts. If, in such cases, the indoor temperature is higher compared with the outdoor temperature a pressure distribution develops from the bottom to the top of the building. The difference in height is the vertical distance from the inlet to the outlet opening

Example: Shaft type building

Given: t_e= 0°C = 273,15 k; t_i= 30°C = 303,15k; ρ=1,275 kg/m³ at 1bar and 0°C.

Calculated: ρ_e= 1,275 kg/m³; ρ_i= 1,149 kg/m³

Δp= 123,6 Pa

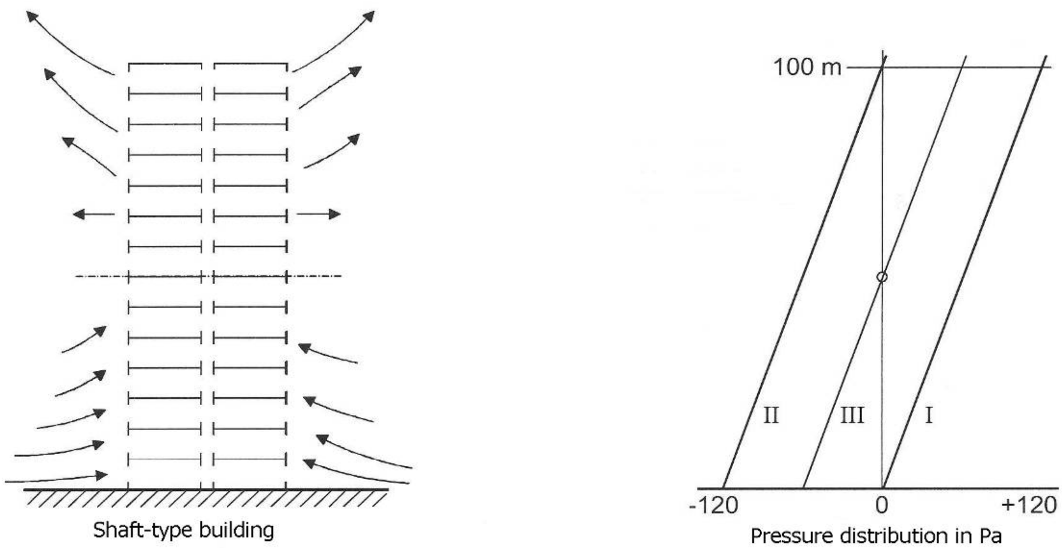


Figure 4.20.: Schematic image of a shaft-type building and its pressure distribution. [38]

The pressure variations in different heights depend on the distribution of leaking areas in the building surface. Three cases are shown in figure 4.20. According to number (I) the building surface is totally air tight except of one opening at the bottom. At the top there is the biggest pressure difference, at the bottom is no difference in comparison with outside conditions. Number (II) represents the inverted case. Number (III) represents the most common case. The leaking areas are regularly distributed over the building surface. Overpressure appears at the top and sub pressure at the bottom of the building. In the middle of the building pressure equality dominates which is also called neutral area. [40]

5 Methodology

The field research took place in Kabale (7/04/2004 -15/04/2004), in Kisoro (21/04/2004 - 02/05/2004), in Mbarara (05/05/2004 – 07/05/2004) and Kalungu (19/05/2004 – 21/05/2004). These places are situated in southern and western Uganda.

5.1 Observation techniques

The observations of dry toilets were based on various tools and instruments of the Rapid Rural Appraisal (RRA) and the Participatory Rural Appraisal (PRA) research method.

5.1.1 Rapid Rural Appraisal (RRA)

RRA was developed in the early 1980s in developing countries as a sociological research method. In this survey method, a multidisciplinary team collects, analyses and values relevant data about rural life and resources. This is achieved by using simple, not standardised techniques, including the knowledge of the local people. The different perception of beneficiaries and the planers are taken into account. Rapid Rural Appraisal is an alternative tool to conventional survey methods, when it comes to a quick estimation of locally present knowledge, potentials and needs.

The basic term of this research technique is community participation, since it was realized that indigenous perception differ from the values of people from "outside". By now, RRA techniques have found widespread application in various purviews and studies

5.1.2 Participatory Rural Appraisal (PRA)

PRA is a further development of the RRA. It emphasizes the take over of an active part in the analyses of problems and planning by the affected persons themselves. Outstanding persons merely act as "facilitators" and play a part in supervising the planning and implementation of the project. PRA sets great store at learning the affected people by inhabitants of a village or a district and a common indication of the local life situation as the basis for jointly planning and executing. Thus, no longer the extern "experts", but the local population is able to feel as the owner of solutions and results determined during the survey. As a result of this research practice the community more likely accepts new solutions and contributes therefore a higher durability of implemented techniques and methods.

The main features of the Participatory Rural Appraisal are:

- Learning within the Community: The main aspect of the PRA is learning from, with, and by members of the community. The team should emphasize with the community members and should therefore be able to see specific problems from their point of view. Involving this indigenous knowledge can greatly facilitate interpretation, understanding and analyses of collected data.

- Triangulation: Describes a form of cross-checking in relation to the multidisciplinary of the team composition, such as men-woman, insiders-outsiders, the comprehensiveness of the information sources (people, places, events and processes) and the variety of tools and techniques.
- Flexibility and Information: Plans and research methods are semi-structured and are revised, adapted and modified as the PRA fieldwork proceeds.
- Optimal Ignorance and Appropriate Imprecision: It assists the PRA team to avoid unnecessary detail and over-collection of data.
- On the Spot Analyses: Learning takes place in the field and the analysis of the information gathered is an integral part of the fieldwork itself.
- Visual Sharing: Describes the collective visual objectification of the project, its problems and possible solutions.
- Offset Biases and Being Self-critical: Helps to interpret and quantify the output and find out falsity of the team itself. The team reflects on what is said and not said, seen and not seen, who is met and not met, and tries to identify possible reasons for errors.

5.1.3 Tools and instruments of RRA and PRA

To transcribe these principles, various tools and instruments have been developed. Their usage and application mainly depend on the local and social situation and have to be, therefore, flexible and adaptable.

- Secondary data-review: Secondary data are sources of background information concerning the project area. This information can be found in documents, reports, photographs, interviews, statistics and maps.
- Semi-structured interview: This is one of the main tools used in PRA. It is a form of guided interview where only some of the questions are predetermined. Questions usually come from the interviewee’s response, the use of ranking methods, observation of the environment and the PRA team’s own background and experience. The interviews also vary in the focus group and the amount of attendants.
- Key indicators: With the help of key indicators it is possible to describe the central problems concerning e.g. wealth, family, structure or access to resources.
- Observation techniques: Direct observation is done to capture phenomena and processes in their typical environment. Furthermore, observation by participating in everyday life enables to experience the community’s prospect.
- Compilation of diagrams, maps and simulation models: These instruments are introduced for planning common discussions and analyses of information gathered. Since only local available materials are used, this tool is very flexible and wide spread. This practice is also suitable to meet the needs and wishes of less eloquent community members.

- Ranking and Scoring: Ranking and scoring means placing something from the quality point of view. Analytical tool, such as ranking, complement semi-structured interviewing by generating basic information which leads to more direct questioning. This tool contains preference ranking, direct matrix ranking or wealth ranking.
- Local knowledge: The use of local methods for knowledge transfer, like songs and poetry, can be helpful to reach the entire spectra of the population.

5.1.4 Critics and limitations of PRA

Although the applications of PRA are numerous and wide ranging, certain considerations should be taken into account by deciding whether PRA is appropriate for specific situations and projects. The most critical elements for a successful study are social competence, qualification and experience of the team members as well as teamwork and additional disciplinary perspectives. Without these attributes PRA may result in questionable findings.

5.2 Investigations

5.2.1 State of the art analysis

In order to meet the objectives set, it was firstly necessary to obtain technical data of the specific installations and information about the user behaviour. After the quantification and interpretation of gained values and information, it should be possible to compare particular conditions and to draw conclusions. The state of the Art analysis activities can be summarized as follows:

- Taking technical data
- Meeting administration officials responsible for dry toilet units
- Meeting with local dry toilet owner and user
- Interviews with operators and owners
- Visiting the South Western Towns Water and Sanitation project in Kabale

5.2.2 Direct observation

The emphasis of this observation was to determine possible reasons for the function or malfunction of different ventilation systems applied on various types of dry toilets. General deliberations have shown that especially climatically conditions, as illustrated in chapter 5.1 “Free ventilation”, have a big impact on the aeration behaviour. For this reason climatically conditions have been captured as follows:

- Air temperature (measurement spots see chapter 5.3)
- Wind direction
- Air flow (measurement spots see chapter 5.3)

5.3 Observations Methods

5.3.1 Measurement spots

The delineated spots below were on the one hand chosen in order to get an expressive temperature distribution of the whole facility and on the other hand to obtain significant information about the air flow between the user and the processing chamber.

Figure 5.1 shows the measurement spots applied on the dry toilet type "Kabale" and "Enviro Loo".

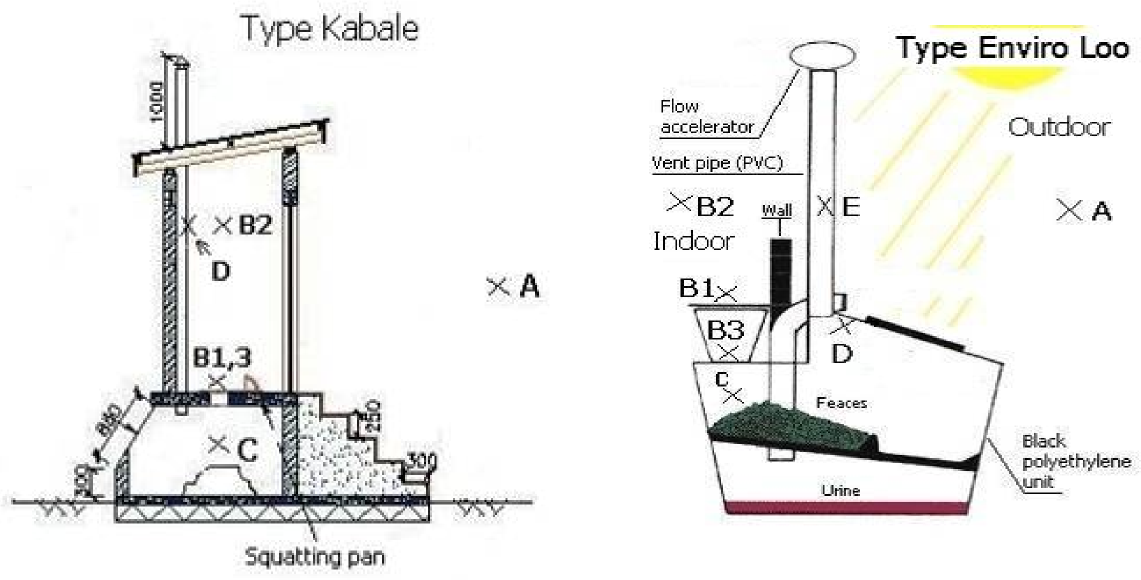


Figure 5.1.: Measurement points of the Kabale- and the Enviro Loo type.

Description type Kabale:

- A Ambient temperature
- B1 User chamber temp., measured above the squatting pan
  Air flow in the squatting hole, measured above the squatting pan
- B2 User chamber temp., measured 1.80 meter above the squatting pan.
- B3 User chamber temp., measured beside the squatting pan, 3-5 cm above the floor.
- C Processing chamber temp., measured above the feaces.
- D Inside pipe temp., measured 1,8m above user chamber floor.

Description type Enviro Loo:

- A to C see above "description type Kabale"
- D Processing chamber temp., measured above the sloping opening.
- E Vent pipe temp., measured inside the pipe at a height of 1,0 Meter above its bottom.

5.3.2 Record time interval

The record time interval was determined in order to require temperature peaks of a day.

Each object was observed over a period of three days. Three measurements a day were taken. The 1st measurement was recorded at 9.00 am, the 2nd measurement at 14 pm and the 3rd measurement at 07.00 pm. These measurements represent the record time intervals of one day. The additional two days have similar record time intervals. Thus, nine measurements were collectively logged at each object.

5.3.3 Measurement execution

The measurement procedure described below is valid for the "Type Kabale" and the "Type Enviro Loo". The measurements were realized according to the record time intervals, explained in chapter 5.3.2 "Record time interval" and the measurement spots, illustrated in chapter 5.3.1 "Measurement spots".

1) Measuring the ambient temperature in point A.
2) Entering the user chamber and closing the door afterwards.
3) Removing the lid, if existing.
4) Preparation of the flow measurement according to step 1-3 of chapter 5.4.3 "Plastic bottle".
5) Measuring the user chamber temp. in point B2.
6) Measuring the user chamber temp. in point B3.
7) Measuring the processing chamber temp. in point C.
8) Measuring temp. in the squatting hole, in point B1.
9) Air flow measurement according to step 3-5 of chapter 5.4.3 "Plastic bottle".

5.4 Measurement device / equipment description

5.4.1 Digital temperature measurement

Producer: Testing Bluhm & Feuerherdt GmbH

Type: Testo DST-K5

Ranges from -199,9 to +1370 °C, depending on probe minimum and maximum function. Calculation of the difference. Basic instrument with 9V (Volt) battery.

5.4.2 Compass

Producer: Eschenbach

Type: 6630 M 1

This march-compass has a plastic case and lid. The needle is situated in fluid-capsule (42 mm diameter) with N/S and O/W lines. The capsule is turn able and has a 360 degree scale. Every second grade is marked. The lid has an interior mirror, arrow markings, march-direction arrow. North marking and the needle peak are phosphorescence.

5.4.3 Plastic bottle

The bottle was a measurement to determine the air flow through the squatting hole. Normally it's used as a liquid reservoir with a volume of two litres. The bottle was subsequently provided with a hole of 7mm diameter. This size of the hole is according to the diameter of a standard cigarette and is added at the bottom of the bottle. Following five steps describe the execution of the air flow measurement.

1) Connecting the lit cigarette to the hole, at the bottom of the bottle.
2) Opening the closure and sucking, until the bottle is opaque and dull. Sucking ten times a row is advised.
3) Storing it next to the squatting hole for at least 3 minutes in order to equalize the smoke temperature to the ambient temperature of the squatting hole. Otherwise the thermal buoyancy would falsify the flow measurement.
4) Exhausting the smoke horizontal over the squatting hole
5) Recording the measured data

6 Results

6.1 State of the art analysis (The present solutions)

The state of the art analysis gives an overview of common and often implemented dry toilet facilities in the south-western regions of Uganda, such as the districts of Kisoro and Kabale. In general the below described facilities can be classified as "Type Kabale" and "Type Enviro Loo".

In the following, three elements of the dry toilet will be described in detail, as follows:

- The vent pipe
- The processing chamber
- The squatting pan

All this mentioned components have an impact on the ventilation process regarding the distribution, dilution and removal of contaminated air and represent therefore key purviews of the state of the art analysis.

6.1.1 Type Kabale

As indicated in figure 6.1, supply/fresh air is entering the user chamber through the rear window and slits of the front door and moves into the processing chamber. From there it enters, indicated as waste air, the environment through the vent pipe.

The delineated air flow in figure 6.1 shows an ideal air movement and hardly is reached on the observed ventilating schemes due to lack of various technical and physical conditions, like insufficient thermal buoyancy and an oversized friction loss through the vent pipes.

Technical drawing (source: SWTWS project)

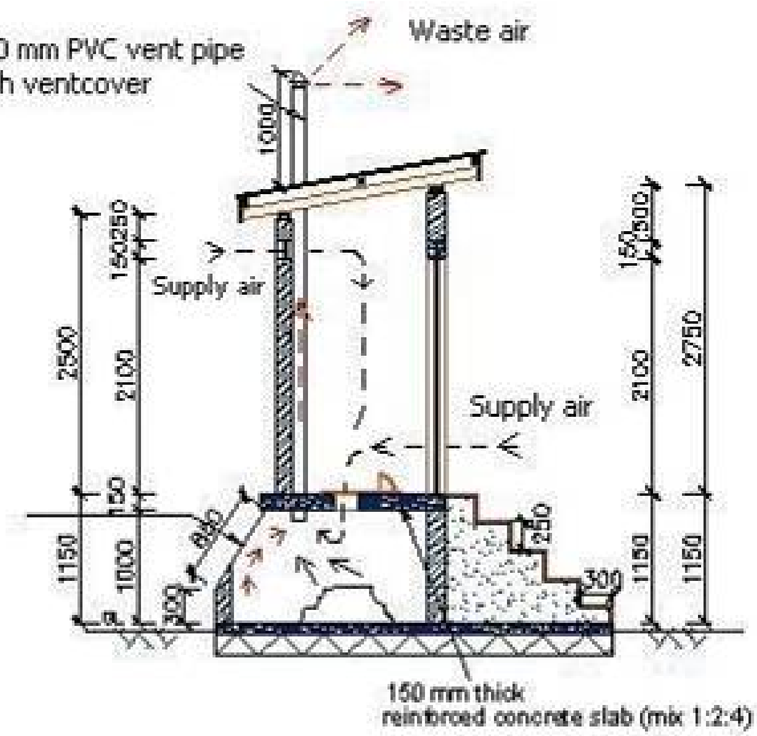


Figure 6.1.: Cross section of a double vault dry toilet – Type Kabale.

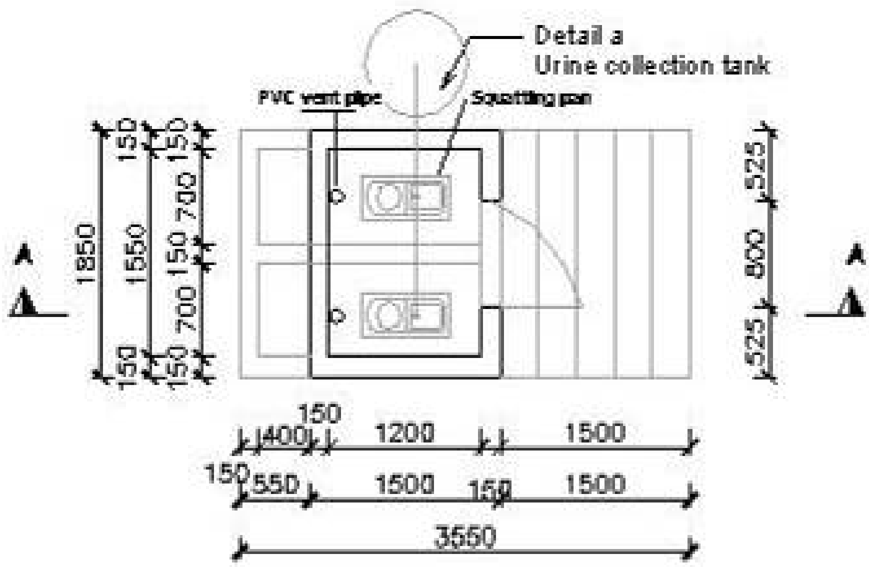


Figure 6.2.: Ground floor – Type Kabale

The Vent pipe

According to the South Western Towns Water and Sanitation Project (SWTWS), in Kabale, the ventilation schema for double vault dry toilets, can either consist of one vent pipe or two vent pipes as shown in figure 6.2. In the first case the pipe is situated in between the chambers with its task to ventilate both chambers. In the second case, each chamber is provided with one vent pipe. In both cases the vent pipe-diameter varies between 90 and 100 mm. Furthermore the vent pipe(s) can either be situated inside the user chamber as illustrated in figure 6.1 above or, on the other side of the rear panel, outside as shown in figure 6.3.

The pipes are all made of synthetic material and the present condition can be assessed from fair to good. In order to calculate the pressure loss through friction, the length and the diameter of the pipes were measured.

The pipes have no uniform rain shelter. Most of them are covered either with a special cover fitting or a self constructed top piece (see figure 6.4). Whereas, the self constructed pieces were mounted, in most cases, directly on top of the pipe, without sufficient space in between. Thus, an air movement through the pipe is inhibited respectively reduced.

Figure 6.3.: Rear view of double vault dry toilets in Kabale. Left picture represents a double vault toilet with two vent pipes. Right image shows a double vault toilet with one vent pipe for both chambers.

Figure 6.4.: Various rain shelters applied on vent pipes. Left picture represents a cover fitting in Bubaale, Kisoro Rd.; Middle image shows a combination of a cover fitting and a self constructed top piece; Right picture indicates a self construction without any space between the pipe and the shelter.

The Processing chamber

The processing chamber obtains either a slanting cover, mainly applied in Kabale, (see figure 6.3) or a vertical opening, mainly applied in Kisoro, in order to seal the chamber during its usage and to be able to remove dehydrated material. The slanting cover acts, beside its function as a door additionally as a solar panel. It increases, in the case of solar radiation, the temperature within the chamber and therefore frames the physical fundamentals of free ventilation (high inside temperature, compared to the outside > low inside density > air is moving upwards). Due to this physical principle a negative pressure appears within the processing chamber, which should provide an air flow from the processing chamber through the vent pipe into the ambient area. Furthermore, an increased processing chamber temperature also quickens the drying process of the expelled faeces.

The doors are all made of metal and are painted black, in order to inhibit corrosion and to increase the door temperature and therefore the processing chamber temperature. The slanting covers have an average size of 600*750 cm (width*hight) to 800*850. The vertical opening sizes vary from 60*50 cm to 55*50 cm.

The Squatting pan

The squatting pans represent the connection between the storage-vault of the feaces and the user area and have to be, therefore, taken into consideration by applying a ventilation system on a dry toilet. The squatting pans applied on dry toilets in Kabala and Kalungu were made of green coloured plastic. The pans constructed on facilities in Kisoro were formed within the concrete slab, as imaged in figure 6.5.

Figure 6.5.: Squatting pans. (f.l.t.r.) 1st and 2nd picture: Plastic pans in Kalungu. 3rd picture: Concrete pan in kisoro. 4th picture: Concrete pan with a lid in Kisoro.

In the case of unfavourable air streams, the squatting pans can be covered with a lid (figure 6.5, 4th picture).

6.1.2 Type Enviro Loo [26]

As reverence serves the viewed facility in Mbarara, a report of the 2nd international symposium on ecological sanitation in Lübeck, 4th -11th April 2003 and the homepage: www.eloo.co.za; product information.

The Enviro Loo is a closed unit without any discharge. It is driven by solar radiation and wind power. The excretions generated by humans are quickly separated, whereas the urine is evaporated to atmosphere. The solids reduce, due to a process of dehydration and aerobic bacterial action, in volume. A odour and pathogen free material is produced which has to be removed, every two to three years, depending on number of users. [41]

Every single toilet is provided with an Enviro Loo unit. It consists of one UV protected polypropylene container, a seat-riser, a low density polyethylene plastic vent pipe, two supply air PVC vent pipes and a flow accelerator on top of the vent pipe.

The ventilating scheme below represents an ideal airflow. It is based on the assumption that solar radiation and wind power are constant weather conditions and therefore deviates from processes in real time, as soon as the previous mentioned weather conditions reduce their values to a specific level. Thus, in the case of no sun and little to zero wind accumulation a breakdown of the ideal airflow scheme is caused.

Schematic drawing (Ventilation scheme)

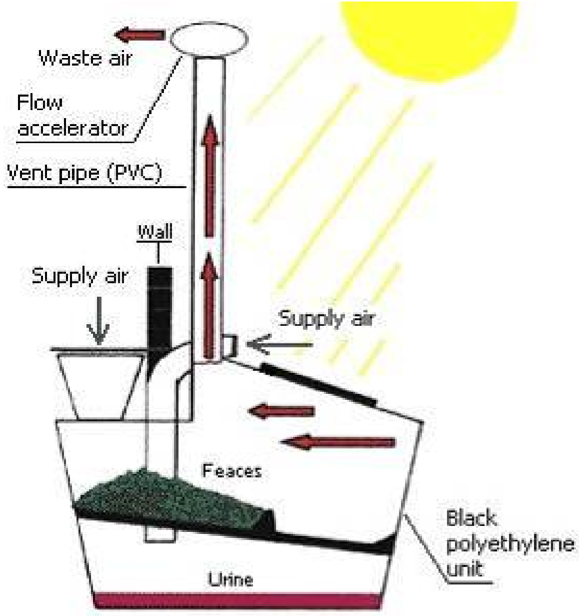


Figure 6.6.: Ventilation scheme – Type Enviro Loo

The ventilation system is, regarding to the previous mentioned reverences, based on the increased internal temperature which causes a negative pressure within the container. This principle generates an air flow from the processing unit, through the vent pipe, to the environment. The supply air enters through both, the supply air pipes (see figure 6.7) and the pedestal into the processing chamber. Within the processing chamber the air is heated up. Thus, the waste air rises and additionally is sucked in the vent pipe due to the flow accelerator, mounted on top of the pipe.

Figure 6.7.: Various parts of an Enviro Loo facility.

The vent pipe

According to the Enviro Opions LTD, the vent pipes are made of black polyethylene plastic with a diameter of 240 mm. The pipe is situated outside, on the rear wall and is connected to the very top of the collecting unit as indicated in figure 6.7.

Figure 6.8.: Rear view of an Enviro Loo facility

The air flow is supported by a flow accelerator, mounted on top of the pipe, which is able to transport a specific amount of volume in dependence of wind velocity. According to a report of the2nd international symposium on ecological sanitation (April 2003) [41], with a relatively low wind speed of 4 km/h an estimated of airflow of 100 to 150 cubic meters can be achieved.

Odour problems can appear when the prevailing is causing a negative pressure on the leeward side as illustrated in figure 6.9. If wind is strong enough it might reverse the airflow through the toilet.

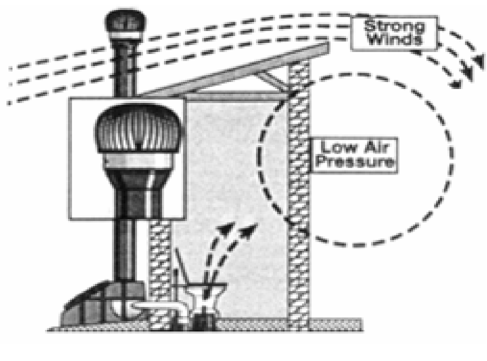


Figure 6.9.: Odour distribution due to unfavourable winds.

The processing chamber

The collecting unit is made of low density polyethylene plastic (see figure 6.7. left picture). It offers the best structural properties with regard to structural strength, flexibility, material lifespan and its inert properties.[41] The black collecting unit is sealed in order to inhibit water infiltration such as ground- and rain –water. The lid is made of the same material as the unit itself and is removable.

The lid respectively the whole unit increases, in the case of solar radiation, the temperature within the chamber and therefore enhances thermal buoyancy. It supports additionally the dehydrating and evaporation process of expelled faeces and urine.

The pedestal

At the observed facility in Mbarara / Rwebitooma market the pedestals were all made off ceramics as illustrated in figure 6.7, right picture. Additionally they are all equipped with a plastic toilet seat and a plastic lid.

6.1.3 Required information about Vent pipe design

According to the CE325 Lecture Notes (Chapter 4:Management of Domestic Sewage, On-Site Sanitation, Makerere University Kampala) a wide variety of materials can be used for vent pipes including PVC, cement, bamboo, cast iron pipes, bricks, etc. The material should be durable, locally available, economic and easy to construct.

The pipe should be at least 0,5m above the highest point of the roof. The internal diameter of the pipe depends on the venting velocity necessary to achieve the recommended ventilation rate of 20 m^3/h. The ventilation rate depends on:

- Internal surface roughness of the pipe
- Length of the pipe
- Head loss through the fly screen and squat hole
- The direction of the wind

Table 6.1.: Recommended Vent pipe diameter (in mm)

Material	Wind speed < 3 m/s	Wind speed > 3 m/s
Cement	150	100
Polyvinyl Chloride (PVC)	150	100
Brick	230	200
Cement-rendered, reed or hessian	230	200
All other rural type e.g. bamboo	230	200

6.2 Direct observation

In the following, only expressive measurement results and observations, based on the recorded data of the checklists, are mentioned. Other measurement results, such as the checklists off all facilities, are listed in chapter "annexes". The checklists contain information about weather conditions, record time intervals, temperature distribution within the toilet and the air flow rating inside the toilet.

Due to insufficient measurement equipment, the air movement within the vent-pipe couldn't be observed. An air flow in the pipe of is imaginable but due to previous mentioned reasons not verifiable.

The previous mentioned effect of wind and sun concerning the air distribution in buildings (chapter 4.2.1 "Free ventilation") could also be monitored at various dry toilet facilities within the scope of the field studies. Thus, the main focus was set, in the following, on describing these physical phenomena and delineated as "Air flow rating due to wind" and "Air flow rating due to sun".

6.2.1 Type Kabale

6.2.1.1 Air flow rating due to wind

6.2.1.1.1 Kisoro, Karumena village

- Date: 21.04.2004 - 23.04.2004
- Name: Mr. Henry Hashakimana
- Vent pipe: ∅ 100 mm; l = 2400 mm; cover fitting

Figure 6.10.: (f.l.t.r.) Front view. Rear view (vertical doors; two outside vent pipes. Detail of the left chamber (vent pipe breakthrough)

Air flow scheme description

As indicated in figure 9.11, the main wind occurred, while recording the data (see checklist, chapter appendix), from east respectively from east to south. Due to wind forces, pressure-differences between the various storefront areas are caused: A high air- pressure area was generated in front of the site, while on the rear side a low air-pressure area was created. As a consequence of this physical phenomenon the air entered, through slits of the front door and the two ventilation bricks beside, the user chamber and further flowed through the squatting hole into the processing chamber. Finally it streamed, indicated as exhausted air, through slits between the processing chamber doors and the rear wall, to the low air pressure area into the environment.

In this connection a positive effect concerning the odour distribution was noticed, as odour was carried away by infiltrated air and therefore wasn't able to contaminate the user chamber by moving upward.

Schematic drawings

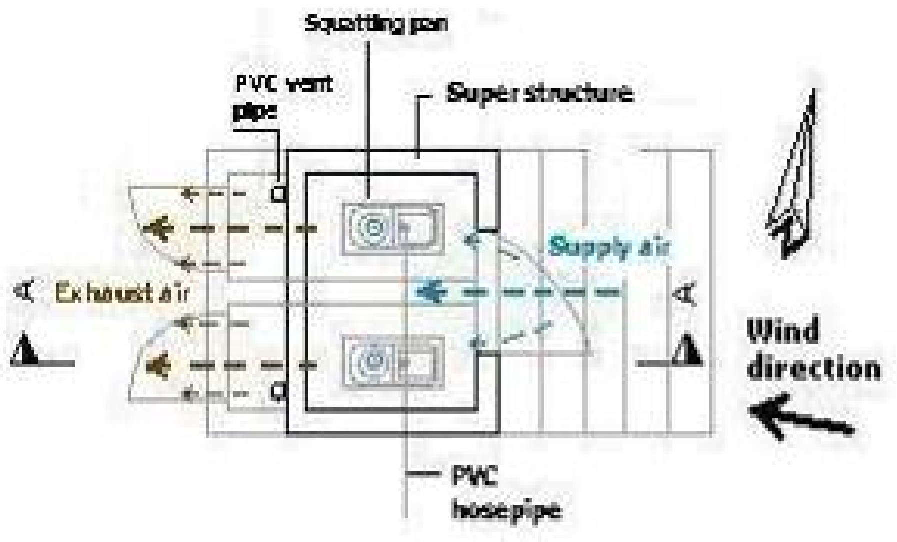


Figure 6.11.: Air flow scheme – ground plan. Kisoro, Karumena Village

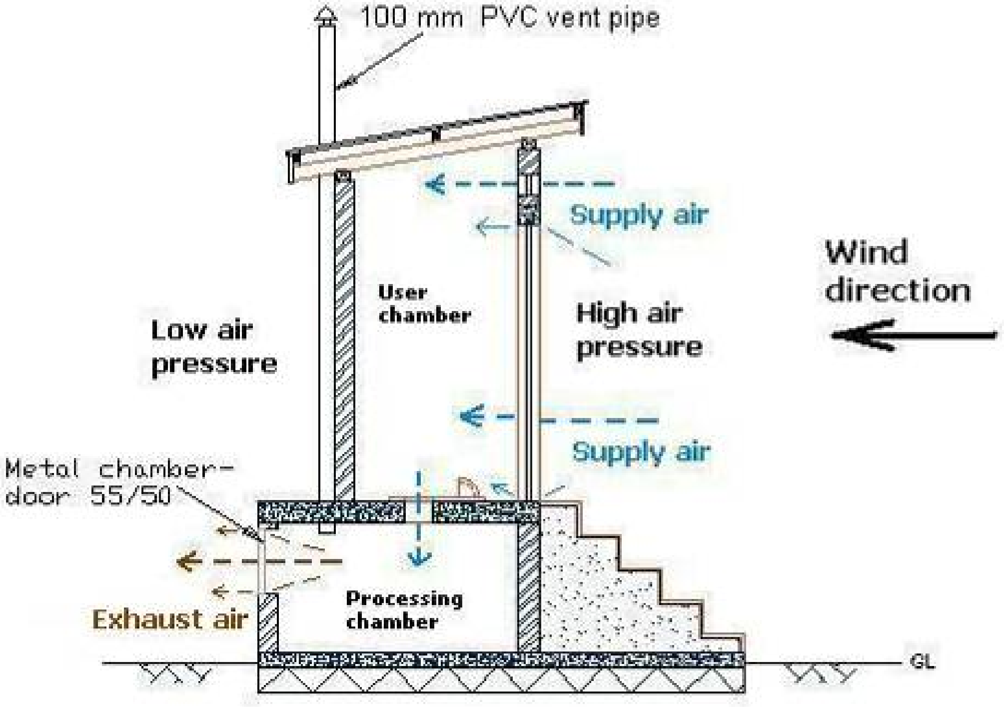


Figure 6.12.: Air flow scheme – section A - A. Kisoro, Karumena Village.

6.2.1.1.2 Kisoro, Mgahinga Nationalpark Office

- Date: 29.04.2004 - 02.05.2004
- Vent pipe: ∅ 110 mm; l= 1900 – 2400 mm; self constructed cover

Figure 6.13.: Twin - double vault dry toilet. (f.l.t.r.) Front view. Rear view.

Air flow scheme description

The illustrated facility is situated in Kisoro and belongs to the Mgahinga National Park Office. It consists of two double vault chamber toilets as imaged in figure 6.14 and was observed over a period of three days, from the 29th of April 2004 to the 02nd of Mai 2004.

As indicated in figure 6.14, the main wind appeared from northeast respectively from north-east to southeast and northwest. That indicates that all measured winds, except the 5th measurement, aim at the rear side of the toilet. Hence a positive air-pressure was caused at the rear side of the toilet and a negative air- pressure at the front building area. In this case air entered through slits, between the processing chamber door and wall, the vault and carried odour contaminated air upward, into the user chamber and further to the high air pressure area.

In this connection a negative effect concerning the odour distribution was noticed, as odour was carried upward into the user chamber by infiltrated air.

Schematic drawing

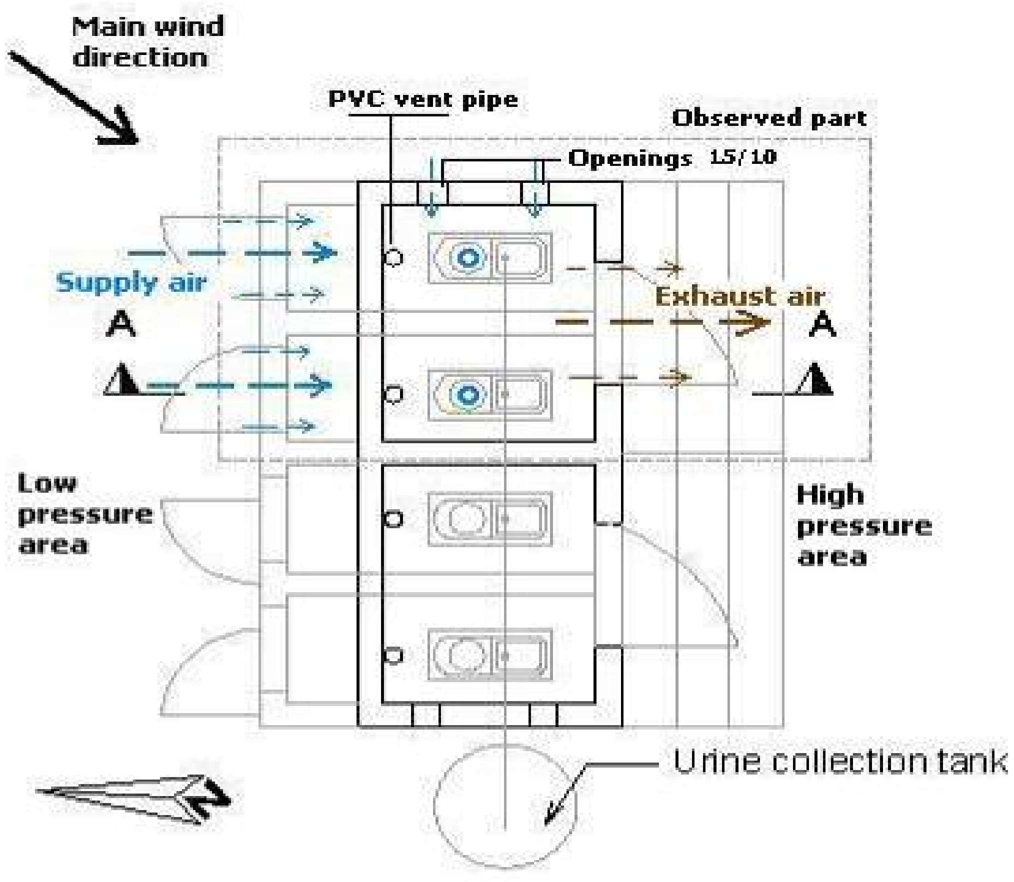


Figure 6.14.: Air flow scheme – ground floor. Kisoro, Mgahinga office.

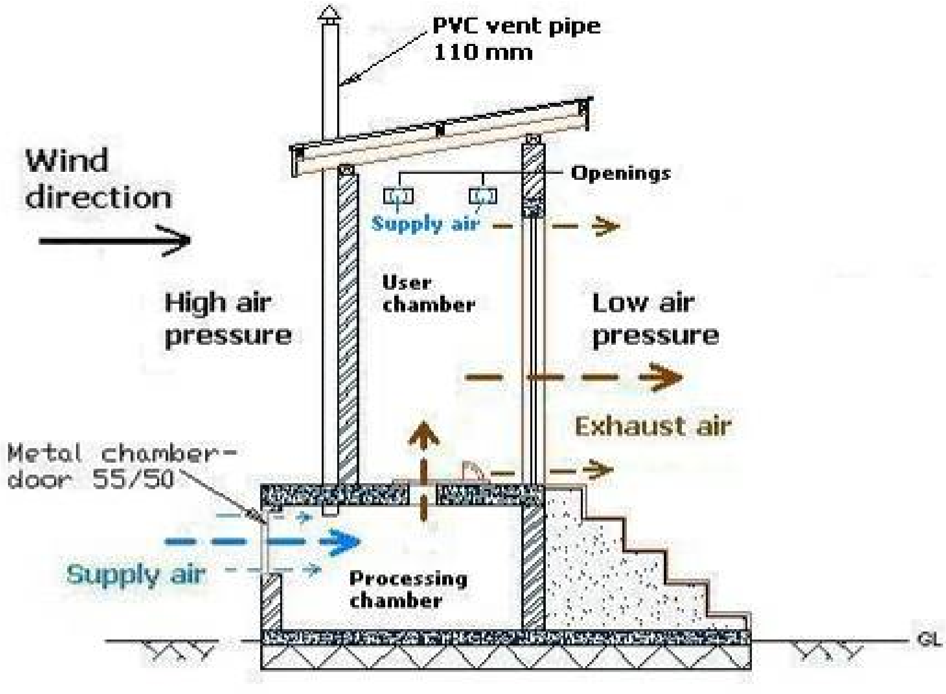


Figure 6.15.: Air flow scheme – section A – A. Kisoro, Mgahinga office.

6.2.1.2 Air flow rating due to temperature

6.2.1.2.1 Kabale, Nyabiconi Rutenga

- Date: 07.04.2004 – 09.04.2004
- Name: Mr. Twayaga
- Vent pipe: ∅ 100 mm; l = 3000 mm; self constructed cover

Figure 6.16.: (f.l.t.r.) Rear view (slanting doors; one outside vent pipe). Processing chamber doors. View inside the left Chamber with the bottom of the vent pipe as indicated.

Air flow scheme description

The schemed facility is situated in Kisoro, Nyabiconi Rutenga and was owned by Mr. Twayaga. It's a double vault chamber toilet with a slanting processing chamber door as imaged in figure 6.16 and was observed over a period of three days, from the 07th of April 2004 to the 09th of Mai 2004.

In the case of sunshine the two processing chamber doors were affected from direct solar radiation till 13.45 pm. From that moment the doors were entire shaded by the roof. The solar radiation caused a heating-up of the black painted steal doors and they further emitted the heat into the chamber. As investigations had shown, a higher processing chamber temperature compared to the ambient temperature was enabled in this connection. The temperature differences varied from 0,8°C to 4,6°C. Therefore, as it is shown in figure 6.18, air raised form the processing chamber into the user chamber and might cause odour problems by taking contaminated air with it.

Only In the case of calm wind the impact of thermal buoyancy can be taken as reliable and expressive. Otherwise the risk of falsified observations cannot be excluded. For this reason three measures, such as the 2nd, the 5th and the 9th have to be seen as irrelevant.

Schematic drawing

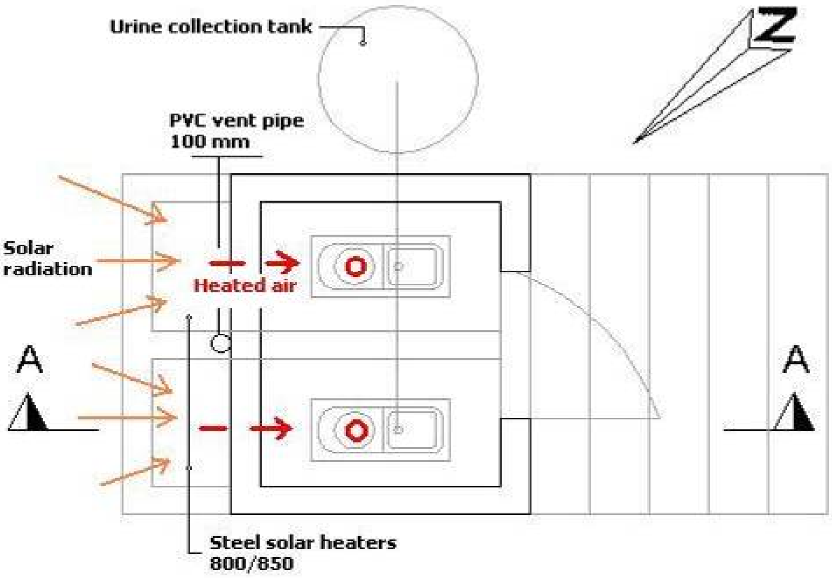


Figure 6.17.: Ground floor plan – Kabale, Nyabiconi Rutenga.

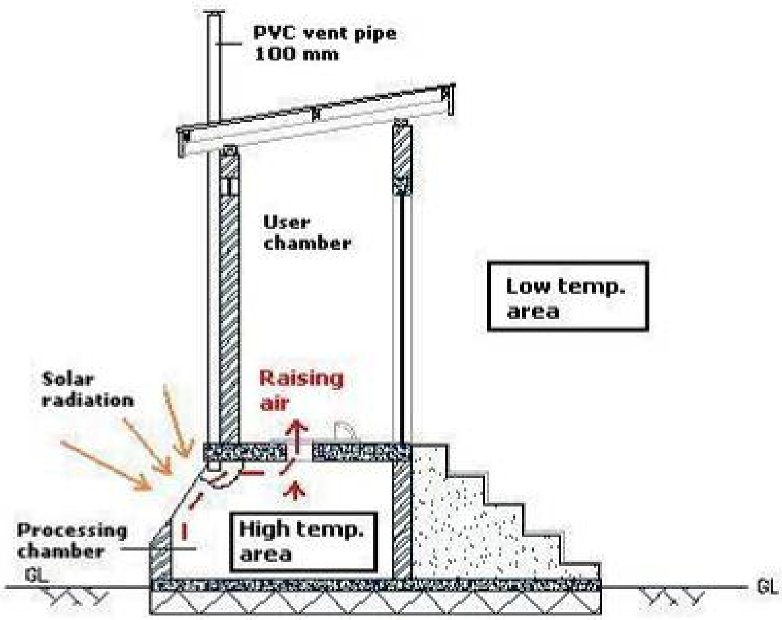


Figure 6.18.: Air flow scheme – section A – A. Kabale, Nyabiconi Rutenga.

6.2.2 Type Enviro Loo

6.2.2.1 Air flow rating due to wind and temperature

6.2.2.1.1 Mbarara, Rwebitoona marked

- Date: 05.05.2004 – 07.05.2004
- Vent pipe: ∅ 240mm; l=2850mm

Pictures of this installation are imaged in chapter 6.1.2 "Type Enviro Loo".

Air flow scheme description

The schemed facility is situated in Marara, Rwebitoona Marked and is a public toilet group of altogether four units as illustrated in figure 6.6. The facility was observed over a period of three days, from the 05th of Mai 2004 to the 07th of Mai 2004.

In the case of emerging natural forces (figure 6.19. left picture), such as solar radiation and winds, a clear air stream from the user chamber through the pedestal to the processing chamber was observed. This stream was, according to quantified observations, mainly generated,

- firstly, due to the increased thermal buoyancy, depending on the intensity of the solar radiation, and
- secondly, due to the flow accelerator mounted on top of the vent pipe, which caused, according to the appearing wind a more or less distinctive low pressure area within the vent pipe respectively the processing chamber.

Additional investigations have shown that in this connection the supply air wasn't sucked through the provided supply air pipes. It can be assumed, that if the storage unit was totally air tight, the supply air would entirely, or at least a great amount of it, be sucked through the pedestal hole. The pedestal lid wasn't closed at any of the three observation days.

A positive effect concerning the odour distribution inside the user chamber was noticed, as odour was carried away by the vent pipe and therefore wasn't able to contaminate the user chamber by moving upward through the pedestal hole. On the other hand, disturbing odours were noticed at surrounding areas of the toilet, which also was confirmed by residents.

In the case of absence of natural forces (figure 6.19. right picture), as already indicated above, only an air stream from the storage unit into the user area was observed. The malfunction of the previously described ventilating scheme (figure 6.19. left picture) can be, according to investigations, related to a breakdown of the thermal buoyancy and a pressure equality of the storage tank/vent pipe to the surrounding area. Hence, disturbing odours within the user chamber were recognized.

Due to insufficient measurement equipment, the air stream within the vent pipe couldn't be monitored. Thus, it wasn't possible to determine if the pipe was totally out of work or just limited.

Schematic drawings

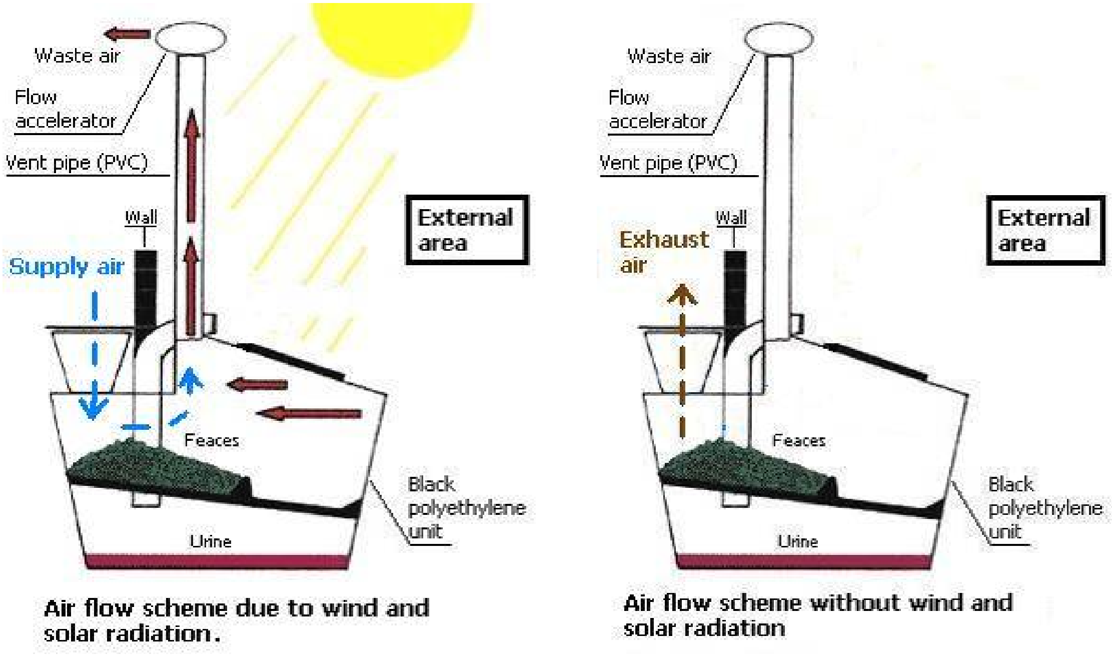


Figure 6.19.: Air flow scheme – Enviro Loo. (f.l.t.r.) Air flow scheme due to wind and solar radiation. Air flow scheme without wind and solar radiation.

7 Recommendations and conclusions

7.1 Technical applications

Table 7.1.: Over-view about the technical applications delineated below. (+= required; -= not required)

Designation	Electr. power	Wind power	Purchase price	Operating costs	Remarks
Extraction vent element (Figure 7.1)	-	-	high	-	Usage of solar radiation is advised
Flow acceler. Without power	-	+	high	-	
Flow acceler. With power	+	-	high	+	
Vent pipe cover	-	-	low	-	
Squatting pan lid - simple	-	-	low	-	
Squatting pan lid – mechanic.	-	-	high	-	
Squatting pan lid - electrical	+	-	high	+	
Vent pipe with a flange	-	-	low	-	Sufficient air-velocity within the pipe

7.1.1 Usage of solar radiation

Since the aim of developing ventilation systems, of this diploma thesis, consider ecological, economical and social aspects such as energy consumption, affordability, simpleness and many more, the usage of natural forces, especially wind energy and solar radiation appear as a appropriate method of resolution. In this connection the implementation of the "Type Kabale" with its slanting processing chamber doors (figure 6.1; 6.3) can be regarded as basic approach, since the air inside the processing chamber is heated up (during periods of emerging sun) and therefore moving upward, if the inside temperature is exceeding the ambient temperature.

To support this process, the processing chamber doors should be orientated south and it should be checked that they aren't shaded by the roof of the superstructure or other objects like plants and other buildings. Now, the consequential increased thermal buoyancy has to be used by leading it into the vent pipe, for example with a component as imaged in figure 7.1. An uncoordinated distribution of the thermal force should be inhibited with such elements. Hence the thermal buoyancy is enlarging the capture area by generating an increased suction effect.

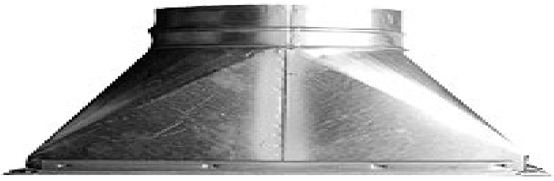


Figure 7.1.: Extraction vent element.

7.1.2 Usage of wind power

The easiest way to use wind power, without consideration of the wind direction, is the application of flow accelerators in connection with an air tight processing chamber surface. The toilet can be faced south, utilizing the solar radiation, without suffering unfavourable odour distribution caused by winds ranging from the same direction. Presupposition for the functionality of that case is certainly an air tight external envelope of the processing chamber, to prohibit an infiltration of air through the processing chamber doors respectively the disconnection of the different pressure areas around the facility.

Without an implementation of flow accelerators, wind forces can only be utilized if the toilet faces the main wind direction with its front door. Hence, air invades through the front door and moves into the processing chamber by taking contaminated air out into the surrounding areas through the slits of the processing chamber doors. If the facility can only be erected with its rear wall (processing chamber doors) facing the main wind direction, the wind force cannot be utilized (in the case of an absent flow accelerator); it's only possible, according to current deliberations and knowledge, to inhibit unfavourable odour distribution by disconnecting the different pressure areas due to squatting pan lids or an air tight processing chamber envelope.

Main wind directions can be obtained at the national meteorological institute or related constitutions, in every country, as far as they exist.

7.1.2.1 Flow accelerator (without power supply)

These wind motioned fans prevent accumulation and increase draught without power connection. Lowest air movements or convecting heat increases the draught as imaged in figure 7.2. In connection with the thermal buoyancy it should be possible to create an adequate air flow, at least during periods of emerging winds and solar radiation. In table 7.2, specific data of various accelerator types are mentioned.

Table 7.2.: Specific data of various types. [42]

Type	Price (Euro)	Duct (mm)	Mean flow-rate (m³/h)
Aspiromatic 160	358,-	80-160mm	125
Aspiromatic 200	375,-	112-200mm	225
Aspiromatic 240	447,-	150-240mm	315

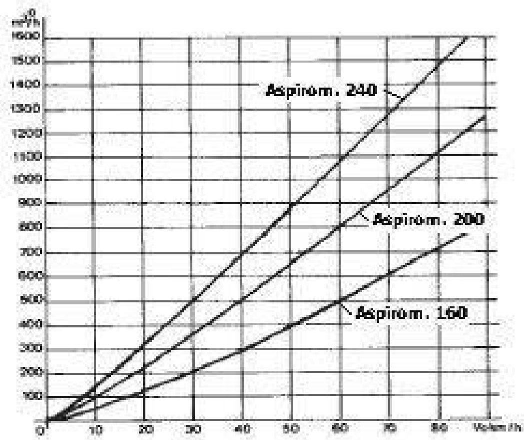


Figure 7.2.: Flow accelerator. (f.l.t.r) Sketch of a flow accelerator. Diagram of the mean flow-rate in correlation with the wind velocity of various types (Aspiromatic 160, 200, 240). [42]

Due to the high procurement costs, as indicated in table 10.1 (European price), of this technical device a recreation in local workstations should be tested.

7.1.2.2 Flow accelerator (with power supply)

Electrical power driven flow accelerators are on the one hand not addicted on adequate weather conditions, since they depend on electric power. A continuous air flow can be generated and therefore contaminated air can be replaced according to user requests. On the other hand, power driven fans are more cost intensive regarding the purchase price and running costs and their implementation require adequate electrical and technical infrastructure, such as power availability/supply beside the availability, maintenance and reparation of technical devices.

To reduce costs respectively to fulfil economical and ecological demands these fans can be realized in order to interact with other technical equipment like a light switch, a motion sensor or odour measurement devices (odour sensor). Due to such applications an effective usage should be enabled.

Table 7.3.: Specific data of a chimney fan. [42]

Type	Price (Euro)	Flow-rate(m³/h) against pressure(Pa)	Voltage (Volt)	Current (Amp.)	Power (kW)
RG 115	486,-	150 m³/h – 20 Pa	230/1 Ph	0,32	0,06
RG 150	685,-	310 m³/h – 30 Pa	230/1 Ph	0,45	0,09

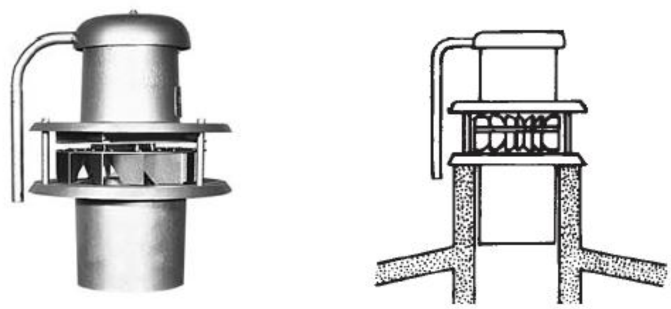


Figure 7.3.: Chimney fan. [42]

7.1.3 Vent pipe cover

In order to inhibit rain water to enter the processing chamber and additionally provide an adequate air stream, vent pipe covers should be constructed according to certain technical rules as follows:

- There should be sufficient space between the top of the pipe and cover, as imaged in figure 7.4. Otherwise the air flow-rate is reduced or impeded.
- The cover should be made out of stainless or less corrosive material like plastic or stainless metal to enhance durability.

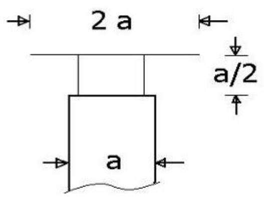


Figure 7.4.: Distance of a vent pipe cover according to the DIN 18910, sheet 2 "Exhaust air duct dimensions".

Further investigations should be done on cover fittings (see figure 6.4 – left picture) and their effect on the air flow rate.

7.1.4 Squatting-pan lid

A squatting pan lid should firstly, restrict unfavourable odour distribution, especially from the processing/storage chamber into the user area, and secondly, inhibit the view into the beneath situated storage vault. Various techniques can be applied in this connection and are categorized regarding their technical effort and outlay below:

- Simple lid, fixed at one end of the squatting pan. This lid is simple in construction and cheap, compared with the types mentioned below. It has to be opened/closed, either with the hand or the foot. (see figure 7.5)

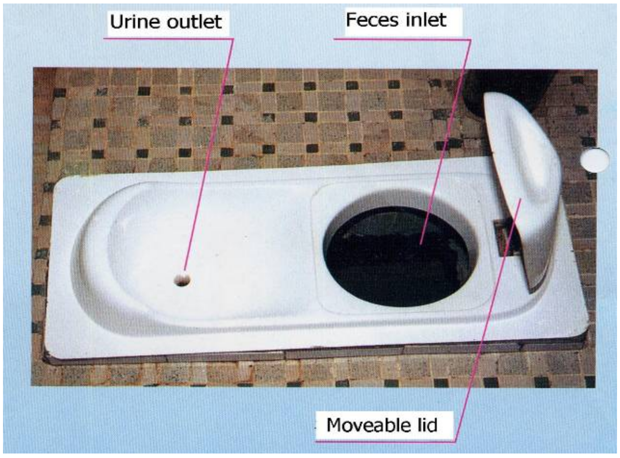


Figure 7.5.: Squatting pan with a movable lid.

- Mechanical lid. This type hasn't been transcribed by now. A number of prototypes must be produced to generate statements about its functionality, expenses, manufacturance, durability and acceptance. Delineated schematic figure 7.6 and figure 7.7 should give an idea about how such technique could be realized.

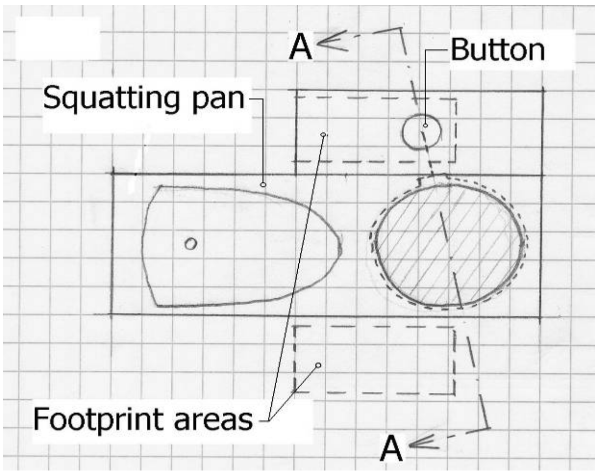
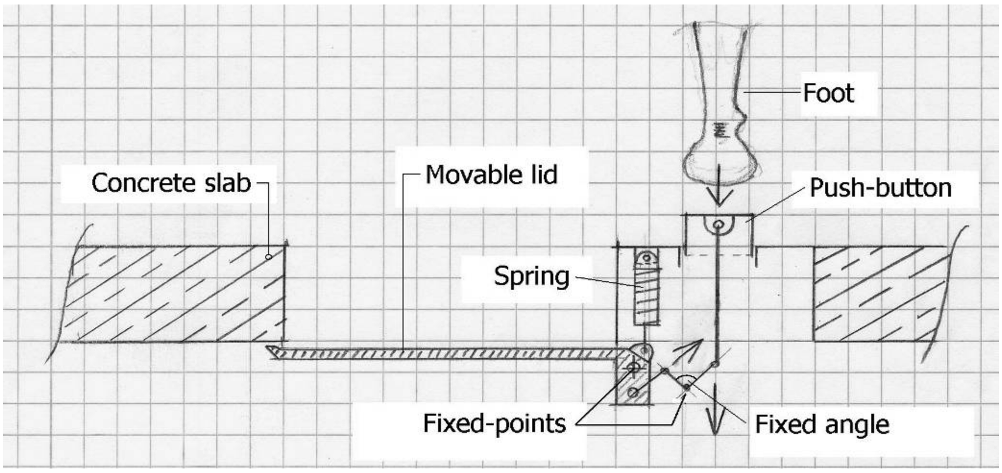


Figure 7.6.: Schematic ground plan of squatting pan with a mechanical lid.



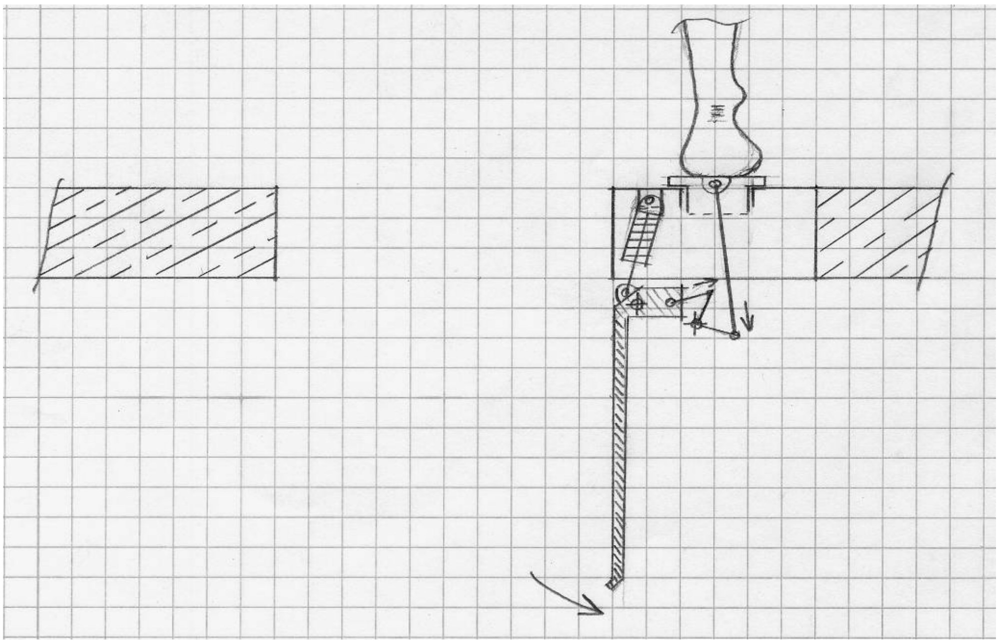


Figure 7.7.: Schematic sketch of a movable lid (Sketch A - A).

- Electrical driven lid. This lid has to be seen as the most expensive and labour intensive application. In contrast to the mechanical lid, human force is replaced by an electrical engine and can be initiated, for example, by an infra-red operating device.

7.1.5 Shaped pieces / capture elements

The usage of capture elements, such as a flange mounted on the bottom of a vent pipe or extraction vent elements (see figure 7.1), leads to an extension of the effective capture area, as illustrated in figure 7.8 and 7.9, and therefore provides a more active and quicker removal of contaminated air. Below imaged figures compare the effective capture area of a standard vent pipe and a vent pipe with a flange.

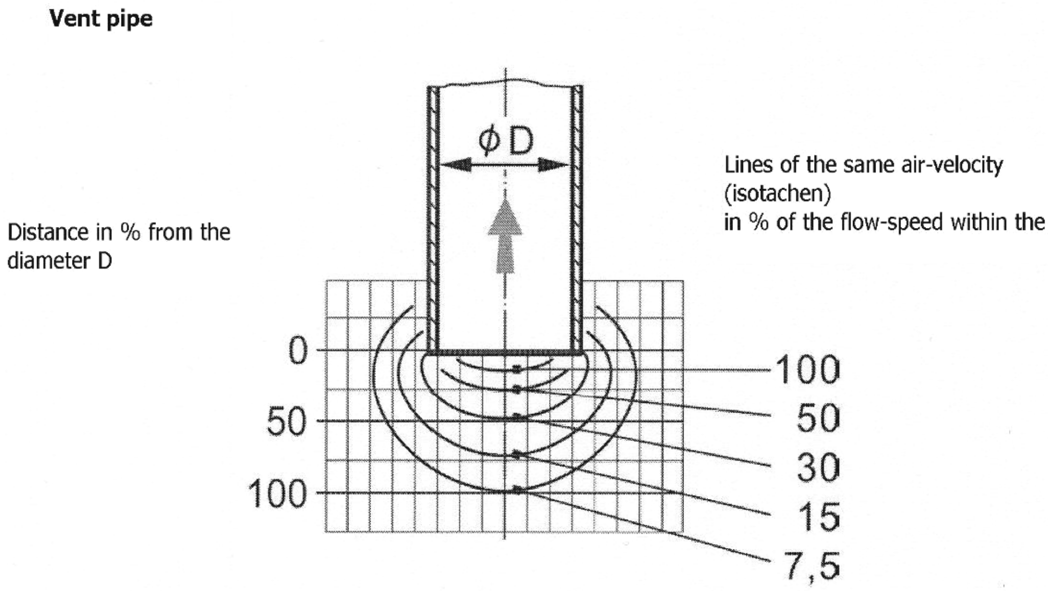


Figure 7.8.: Standard vent pipe with its effective capture area. [43]

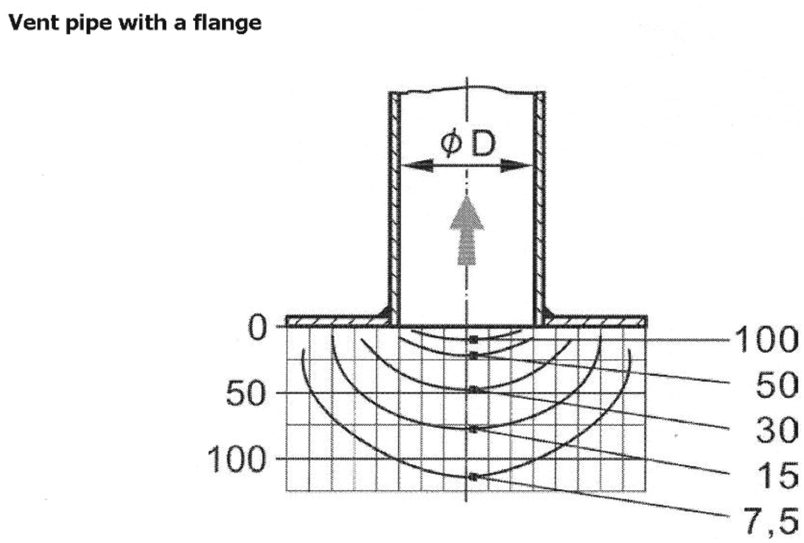


Figure 7.9.: Vent pipe with a flange and its effective capture area. [43]

7.2 Facility design

7.2.1 Vent pipe diameter

The prime costs and the function of a ventilation system mainly depend on the pipeline construction. Higher velocities beside smaller diameters imply less system costs, yet the increasing pressure loss causes higher operating costs at mechanical ventilated facilities. According to physical fundamentals represented in chapter 4.4.1

"Stream equation", the pressure loss is changing with the quadrate of the velocity. Therefore a high air velocity, due to small diameters, could cause a ventilation breakdown, if the air is not able the overcome the likewise increased friction resistance.

Especially at a free ventilation system it is aimed to reduce air resistances, caused by pipe friction, shaped pieces (bows, reductions..) and installations (filter, sound absorber..), for example due to the application of a bigger pipe diameters, because in this case forces to generate an air movement are limited and not steady, since they depend on winds and temperature differences.

In connection with the "Type Kabale", recommendations about the vent pipe diameter wouldn't be reliable. On the basis of the investigations it only was possible to monitor, in dependence on the particular wind direction, an air flow from the user chamber into the storage chamber and further through the processing chamber door into the environment and the other way around. Future investigations in this connection should focus on the interaction between diameter, length of the pipe and thermal buoyancy, especially in view of the so called "chimney-effect".

The applied vent pipe diameter, on the dry toilet facility "Type Enviro Loo", of 240mm has to be seen as adequate, since the monitored air flow, in the case of present natural forces, served the user demands concerning the odour elimination.

7.2.2 Storage above the ground

The bottom of a processing chamber in Kisoro/ Karumena Village is measured – 0,10m below ground level. In such cases an infiltration of rainwater, which leads to a retarding drying process, is only with additive technical and financial effort preventable, such as a waterproof tray at the bottom of the chamber. Therefore, a minimum height, of the processing chamber bottom of ± 0,00m above the ground is recommended.

7.2.3 Exhaust direction

According to the DIN 18017 "Ventilation of bathrooms and WCs without outside windows by fans", the exhaust direction of the vent pipe highly affects its functionality. Hence, to inhibit interrupting pressure due to winds, the air should always be expelled vertical to the ground-surface (sea surface). If exhaust air is expelled horizontal to the ground, an unfavourable odour distribution can be caused, since the air flow in the pipe is reduced or even reversed and contaminated air is prevented of being removed or pushed from the processing chamber into the user chamber.

7.3 Recommendations on further investigations

- Investigation of the interaction between the length of pipe, diameter and the thermal buoyancy (Chimney effect) according to the ÖNORM M 7515 – Berechnungen von Fangmessungen (Calculation of Chimney hoods).
- On the basis of various trials, the usability, importance and feasibility of different technical applications (flow accelerator, squatting-pan lid, vent pipe cover..) and other parameter (sun, wind, thermal buoyancy..) should be determined.
- Comparison of the costs of technical components and their utility.
- Odour absorption of dehydrating materials. Comparing ash, lime, soil, sand, cow dung and others.
- Comparison of a dry toilet with a slanting door (solar panel) and a horizontal processing chamber door under the same conditions (weather, orientation, structure dimensions) regarding the odour accumulation, the drying process and the thermal buoyancy.

8 Summary

Uganda is still one of the poorest countries in the world and is faced with an abundance of economic, social and environmental problems. Even the will and the motivation for development are remarkable and lead to significant success.

Dry toilet facilities are an appropriate solution to the sanitation problem, since they improve sanitation provision where required, reduce respectively inhibit water pollution, encourage water conservation and recover and recycle nutrients and organic matter.

In order to support recent developments regarding alternative water and sanitation concepts many research scientists work on different strategies, aiming new concepts for a self-sustaining and affordable sanitation systems which also meets the acceptance of the users. One of these new methods of solutions is based on the separation of urine and faeces and is indicated as dry toilet. This technology is part of a closed loop system, where human excreta are handled as a resource and where these excretions are stored and treated on site.

But the storage and treatment of human excretions on site also causes various problems, such as an unfavourable distribution of contaminated air towards the user area. Therefore, the main focus of this work was on finding solutions with which it should be possible to reduce respectively to eliminate the odour in the user-chamber of the dry toilet and its surrounding area. Thus, various facilities in the south-western part of Uganda, such as Kabale, Kisoro, Kalungu and Mbarara were visited and observed over a period of three month, from the 12th of March to the 12th of June.

Series of measurements and close-ups of existing installations gave an over-view about the quality and efficiency of the implemented ventilation schemes. The observed toilets were categorized as "Type Kabale" and "Type Enviro-Loo", whereas the ventilation technique of the first mentioned type can roughly be described as simpler, cheaper and less advanced in comparison with the aeration technique of the Enviro-Loo toilet.

Due to the quantification of recorded data and interviews, it was possible to find specific solutions with the aim of finding new components and the adaptation of already existing parts, regarding facility design and technical applications as follows:

Technical applications:

- Flow accelerator (with/without power supply)
- Shaped pieces/capture elements
- Vent pipe cover
- Squatting-pan lid (standard, mechanical, electrical)

Facility design:

- Storage above the ground
- Consideration of the exhaust air direction
- Situation of the toilet according to the main wind/sun appearance
- Vent pipe diameter

With these measures and deliberations it should be possible to improve future dry toilet implementations in view of aeration techniques and related design purviews, whereas it has to mentioned that only the observation of practical implemented constructions allow statements about their functionality and feasibility.

However, the further development of the dry toilet in view of aeration-technologies and other purviews with the consideration of social, financial and technical parameter is highly important to create a product, which is able to meet the requirements of modern conventional sanitation facilities in order to be an accepted alternative option to them.

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9.2 List of figures

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10 Appendix

Checklists

A Kabale, Nyabikoni – Rutenga

B Kabale, Kitumba – Katuna Rd.

C Kabale, Bubaale – Kisoro Rd.

D Kisoro, Karumena Village, Mr. Hashakimana

E Kisoro, Karumena Village

F Kisoro, Mgahinga Nationalpark Office

G Kalungu, Sacred Heart Sisters

H Mbarara, Enviro Loo

Checklist – Drytoilets — Uganda

Date: 07.04.2004 – 09.04.2004

Location: Kabale, Nyabikoni - Rutenga

Facility: double vault unit; slanting rear lid; plastic squatting pan

Name: Mr. Twayaga

Vent pipe: ∅ 100 mm; l = 3000 mm; self constructed cover

Cleaning material: paper sheets

Dehydrating agent: ash, dry soil

Fly breeding: not recognizable

	Time	Weather		Temperature (°C)					Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C		
1. Mst	10.15	no wind	coudy	21,7	20,5	21,2	21,3	20,0	-	light
2. Mst	14.00	S to E	sunny, cloudy	25,1	25,4	26,2	22,2	25,1	↑↓	light
3. Mst	19.00	no wind	cloudy, sun set	20,0	24,1	24,6	22,9	24,1	↑	medium
4. Mst	09.00	no wind	dull	15,8	20,3	18,2	18,0	20,2	↑	medium
5. Mst	14.00	S to E	cloudy, sunny	24,2	25,7	23,8	22,0	24,2	↑↓	medium
6. Mst	19.00	no wind	clear, sun set	18,7	23,3	24,6	22,7	23,3	↑	medium
7. Mst	09.00	no wind	dull	16,0	19,5	18,7	18,2	19,9	↑	light
8. Mst	14.00	no wind	sunny, cloudy	24,7	25,3	24,7	21,9	25,5	-	light
9. Mst	19.00	E	clear, sun set	20,3	23,9	24,9	23,4	23,7	↑	light

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: Ø....diameter; l.....length

Odor: strong, medium, light, not recognizable

Air flow:
- ↑ up, from processing chamber to user chamber
- ↓ down, from user chamber to processing chamber
- ↑↓ changeable air flow
- – not recognizable air flow

Checklist – Drytoilets Uganda

Date: 10.04.2004 – 12.04.2004

Location: Kable, Kitumba – Katuna Rd.

Facility: double vault unit; slanting rear lid; squatting pan

Name: Mr. Mwesigye Charles

Vent pipe: ∅ 100 mm; l = 3500 mm; covered pipe

Cleaning material: paper sheets

Dehydrating agent: ash

Fly breeding: not recognizable

	Time	Weather		Temperature (°C)					Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C		
1. Mst	09.00	no wind	dull	16.6	19.8	20.8	19.4	20.1	↑	light
2. Mst	14.00	E	cloudy	21.6	22.1	24.4	22.7	21.3	↑↓	light
3. Mst	19.00	no wind	dull; sun set	19.5	21.2	23.8	22.3	21.1	-	light
4. Mst	09.00	no wind	dull	17.7	19.7	20.2	19.6	19.8	↑	light
5. Mst	14.00	no wind	cloudy, sunny	25.1	23.7	25.9	23.1	22.5	-	light
6. Mst	19.00	no wind	clear, sun set	16.8	20.4	21.5	20.8	20.4	-	light
7. Mst	09.00	no wind	dull	17.6	19.3	20.2	19.0	19.4	↑	light
8. Mst	14.00	E	cloudy	22.2	21.7	24.0	22.4	21.1	↓	not recog.
9. Mst	19.00	no wind	dull; sun set	19.2	21.1	23.2	22.0	21.1	-	light

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: Ø....diameter
l.....length

Odor: strong
middle
light
not recognizable

Air flow:
↑ up, from processing chamber to user chamber
↓ down, from user chamber to processing chamber
↑↓ changeable air flow
– not recognizable air flow

Checklist – Drytoilets Uganda

Date: 13.04.2004 – 15.04.2004

Location: Bubaale, Kisoro Rd.

Facility: double vault unit; slanting rear lid; concrete squatting pan

Name: Mr. Nizeye Imaana

Vent pipe: ∅ 120 mm; l = 2800 mm; cover fitting

Cleaning material: paper sheets

Dehydrating agent: ash, if present

Fly breeding: few flies in processing chamber

	Time	Weather		Temperature (°C)					Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C		
1. Mst	09.00	no wind	dull	19,1	19.8	22,4	20,1	19,7	-	medium
2. Mst	14.00	E	cloudy	18,7	20,2	21,6	20,1	20,1	↑	strong
3. Mst	19.00	no wind	cloudy	17,8	20,3	22,2	20,2	20,3	-	medium
4. Mst	09.00	no wind	dull	16,4	17,9	19,5	17,8	18,6	↑	medium
5. Mst	14.00	S/E	cloudy, rainy	16,3	18,5	19,3	18,5	18,6	↑	medium
6. Mst	19.00	no wind	cloudy	16,2	18,9	19,6	18,6	18,9	↑	medium
7. Mst	09.00	no wind	dull	16,1	17,2	18,4	16,6	17,5	↑	medium
8. Mst	14.00	S	cloudy, rainy	17,0	19,4	20,6	18,9	19,4	↓	light.
9. Mst	19.00	no wind	cloudy	17,4	19,6	21,1	19,7	19,6	-	medium

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: Ø….diameter
l…..length

Odor: strong
middle
light
not recognizable

Air flow:
↑ up, from processing chamber to user chamber
↓ down, from user chamber to processing chamber
↑↓ changeable air flow
– not recognizable air flow

Checklist – Drytoilets Uganda

Date: 21.04.2004 – 23.04.2004

Location: Kisoro, Karumena village

Facility: double vault unit; slanting rear lid; concrete squatting pan

Name: Mr. Henry Hashakimana

Vent pipe: ∅ 100 mm; l = 2400 mm; cover fitting

Cleaning material: paper sheets

Dehydrating agent: none

Fly breeding: not recognizable

	Time	Weather		Temperature (°C)					Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C		
1. Mst	09.00	E	sunny	21,9	20,5	24,0	20,4	18,6	↓	not recog.
2. Mst	14.00	E	sunny	24,3	22,5	27,6	22,6	22,2	↓	not recog.
3. Mst	19.00	no wind	clear; sun set	18,6	21,2	22,4	21,2	20,7	-	medium
4. Mst	09.00	E	cloudy	16,3	16,9	18,6	16,6	17,5	↓	not recog.
5. Mst	14.00	E	cloudy	21,4	20,9	22,9	21,7	20,2	↓	not recog.
6. Mst	19.00	E to S	sun set	18,0	19,9	20,1	19,3	20,0	↓	not recog.
7. Mst	09.00	E	sunny, cloudy	18,3	18,5	19,5	18,7	18,0	↓	not recog.
8. Mst	14.00	E	sunny	25,2	24,0	27,3	24,4	22,4	↓	not recog.
9. Mst	19.00	E	clear, sun set	20,3	21,7	22,3	21,6	21,7	↓	not recog.

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: ∅….diameter
l…..length

Odor: strong
middle
light
not recognizable

Air flow:
↑ up, from processing chamber to user chamber
↓ down, from user chamber to processing chamber
↑↓ changeable air flow
– not recognizable air flow

Checklist – Drytoilets — Uganda

Date: 24.04.2004 – 26.04.2004

Location: Kisoro, Karumena village

Facility: double vault unit; slanting rear lid; plastic squatting pan

Name: Mrs. Turyamureeba Anne B.

Vent pipe: ∅ 100 mm; l = 2500 mm; cover fitting

Cleaning material: paper sheets

Dehydrating agent: sawdust

Fly breeding: not recognizable

	Time	Weather		Temperature (°C)					Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C		
1. Mst	09.00	E	dull	20.5	18.7	22.5	19.6	18.5	-	light
2. Mst	14.00	SSE	cloudy	21.9	19.7	25.1	20.7	19.3	↑↓	light
3. Mst	19.00	no wind	clear; sun set	17.8	21.0	24.3	21.0	20.3	-	light
4. Mst	09.00	SSE	cloudy	17.5	18.2	20.4	18.4	18.7	↑↓	medium
5. Mst	14.00	SSE	sunny; cloudy	23.2	21.8	28.3	23.5	21.0	↑↓	not recog.
6. Mst	19.00	S	cloudy, sun set	17.8	22.0	22.8	21.6	21.1	↓	light (sweet)
7. Mst	09.00	SSE	sunny	19.2	18.4	21.9	18.4	18.5	↑↓	light
8. Mst	14.00	SE	sunny; cloudy	25.3	23.9	31.0	25.4	22.5	↑↓	light (sweet)
9. Mst	19.00	nowind	cloudy, sun set	19.3	22.5	25.5	22.5	22.3	-	medium

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: Ø….diameter
l…..length

Odor: strong
middle
light
not recognizable

Air flow:
↑ up, from processing chamber to user chamber
↓ down, from user chamber to processing chamber
↑↓ changeable air flow
– not recognizable air flow

Checklist – Drytoilets — Uganda

Date: 29.04.2004 – 02.05.2004

Location: Kisoro, Mgahinga Nationalpark Office

Facility: double vault unit; vertical rear lid; concrete squatting pan

Name:

Vent pipe: ∅ 110 mm; l = 1900 - 2400 mm; self-constructed cover

Cleaning material: paper sheets, toilet paper

Dehydrating agent: none

Fly breeding: Flies in processing / user chamber

	Time	Weather		Temperature (°C)					Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C		
1. Mst	09.00	NE	sunny	19,7	18,6	21,4	18,2	18,6	↑	medium
2. Mst	14.00	NE to SE	sunny, cloudy	25,1	23,8	29,3	24,3	21,8	↑↓	strong
3. Mst	19.00	NE	rainy; sun set	17,0	20,4	21,4	21,4	20,2	↑	strong
4. Mst	09.00	NE	dull	20,6	18,2	19,9	17,7	18,6	↑	strong
5. Mst	14.00	NS to SW	cloudy	20,2	20,9	24,2	22,1	20,8	↑↓	medium.
6. Mst	19.00	NW	sun set	16,2	19,5	20,8	19,8	19,4	↑	strong
7. Mst	09.00	N to NE	sunny, cloudy	17,7	17,6	18,2	17,0	17,7	↑	strong
8. Mst	14.00	NE	Sunny, cloudy	24,9	22,2	30,2	23,2	21,0	↑	strong
9. Mst	19.00	NE	sun set	16,1	19,9	21,6	20,8	19,5	↑	medium

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: Ø….diameter; l…..length

Odor: strong; middle; light; not recognizable

Air flow:
- ↑ up, from processing chamber to user chamber
- ↓ down, from user chamber to processing chamber
- ↑↓ changeable air flow
- – not recognizable air flow

Checklist – Drytoilets — Uganda

Date: 19.005.2004 – 21.05.2004

Location: Kalungu

Facility: toilet group; vertical rear lid; plastic squatting pan

Name: Sacred Heart Sisters

Vent pipe: ∅ 100 mm; l = 3500 mm; covered pipe

Cleaning material: paper sheets, toilet paper

Dehydrating agent: ash

Fly breeding: not recognizable

Remark: To measurement spot D =>Vent pipe only gets sun till 13.00 am

	Time	Weather		Temperature (°C)						Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C	D		
1. Mst	11.00	SE	cloudy	27,3	26,1	28,3	26,3	25,3	31,3	↑	medium
2. Mst	14.00	SE	sunny	28,4	26,7	31,9	28,2	25,8	28,7	↑	medium
3. Mst	19.00	SE	clear; sun set	22,8	24,6	29,7	27,0	23,8		↑	medium
4. Mst	09.00	no wind	sunny	23,3	26,2	25,3	23,0	24,4	29,1	↑	light
5. Mst	14.00	NE	cloudy	24,3	26,3	28,8	26,5	25,6	26,7	↑	light
6. Mst	19.00	no wind	cloudy, sun set	21,6	23,6	26,5	25,2	23,2	21,2	↑	light
7. Mst	09.00	SE	sunny	20,1	24,6	23,6	21,6	23,1	27,0	↑↓	medium
8. Mst	14.00	SE	sunny; cloudy	26,5	27,1	30,3	28,5	26,0	28,3	↑↓	medium
9. Mst	19.00	E	clear; sun set	21,6	24,4	27,1	26,0	23,7		↑	medium

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: Ø….diameter; l…..length

Odor: strong, middle, light, not recognizable

Air flow:
- ↑ up, from processing chamber to user chamber
- ↓ down, from user chamber to processing chamber
- ↑↓ changeable air flow
- – not recognizable air flow

Checklist – Drytoilets Uganda

Date: 05.05.2004 – 07.05.2004

Location: Mbarara – Rwebitoona Market

Facility: Enviro Loo; toilet group

Name: not available

Vent pipe: ∅ 240 mm; l = 2850 mm

Cleaning material: paper sheets, toilet paper

Dehydrating agent: none

Fly breeding: flies in the processing / user cahmber

	Time	Weather		Temperature (°C)							Air flow	Odor
		Wind-direction	Other conditions	A	B1	B2	B3	C	D	E		
1. Mst	09.00	W	sunny	22,1	20,0	20,8	19,9	20,8	-	-	↑	medium
2. Mst	14.00	E	sunny, cloudy	28,3	27,9	29,2	26,0	27,2	-	32,2	↓	medium
3. Mst	19.00	no Wind	clear; sun set	24,2	22,3	25,9	23,6	23,1	-	23,1	↑	medium
4. Mst	09.00	E	sunny	21,8	21,5	23,5	21,8	22,0	31,3	28,2	↓	light
5. Mst	14.00	SE	sunny	28,1	27,1	28,1	26,6	26,9	36,6	31,6	↓	light
6. Mst	19.00	E	clear, sun set	23,5	24,7	25,5	24,7	23,8	22,8	22,8	↑	light
7. Mst	09.00	W	cloudy	22,9	21,8	22,9	21,8	21,9	24,7	24,3	↓	medium
8. Mst	14.00	E	sunny; cloudy	27,2	27,0	28,5	26,5	26,8	36,3	36,0	↓	medium
9. Mst	19.00	no wind	cloudy; sun set	23,9	22,9	25,8	24,7	23,0	23,4	23,3	↑	medium

Notice: The inaccuracy of the direction - degrees ranges from +5° to –5° !
Sun set at 18.30 !

Legend:

Vent pipe: Ø....diameter
l.....length

Odor: strong
middle
light
not recognizable

Air flow:
↑ up, from processing chamber to user chamber
↓ down, from user chamber to processing chamber
↑↓ changeable air flow (≥3 times in other direction)
– not recognizable air flow