The Improvement of Ventilated Improved Pit Latrine Sanitation Systems

by

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Dedication

Cette thèse est dédié à tous mes amis à Ouagadougou qui m'ont ouvré leurs maisons et leurs vies. Barika.

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As is the case with any work of considerable scope, this thesis could not have been completed without the help of many people.

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Abstract

Burkina Faso is a country in the Sahel of West Africa struggling, like many developing nations, with the problem of providing adequate sanitation to its poorest regions. Inadequate sanitation is responsible for many health problems and results in much lost potential, thus exacerbating the country's economic and social problems.

In response to this need, sanitation workers developed the ventilated improved pit (VIP) latrine in the mid 1980's. The VIP latrine was designed to overcome the odour and fly problems common in ordinary pit latrines with the installation of a ventpipe to ventilate the latrine pit. An emphasis on inexpensive fabrication and the fact that the VIP latrine does not require water, makes the VIP latrine ideal for use in the remote regions of Burkina Faso.

Since its design, thousands of VIP latrines have been installed throughout Africa. However, reports of poor operation resulting in a return of the odour and fly problems of older latrines have been received. It was decided that the VIP latrine was an important part of the sanitation plans for Africa and that an investigation of these problems was warranted.

This project investigated the ventilation of the VIP latrine and attempted to find a way to improve the ventilation rate. Three accessories, a venturi, a slotted fitting and a diverging

fitting placed at the outlet of the ventpipe, were considered as possible methods of achieving this end. The fittings were analyzed theoretically and tested in the laboratory and in the field.

The results of the tests showed that the divergent fitting was no more effective in inducing up-flow than the open pipe. The slotted fitting produced significant improvement over the open pipe for wind speeds greater than 1.3 metres per second. The venturi fitting produced an improvement in the ventilation rate for all wind speeds, however this improvement was slightly smaller than that of the slotted fitting. Given that the slotted fitting is significantly more expensive than the venturi and that the wind in Burkina Faso is such that the slotted fitting would be effective for only a small portion of the year, it was concluded that the most appropriate accessory is the venturi.

The field portion of this project was conducted in Ouagadougou, Burkina Faso with the aid of Centre régional pour l'eau potable et l'assainissement à faible coût (CREPA).

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Glossary

AGRHYMET	Centre régional de formation et d'application en agrométéorologie et hydrologie opérationnelle
CFA	Communauté financière africaine
CIDA	Canadian International Development Agency
CILSS	Centre international pour la lutte contre la sécheresse sahélienne
CREPA	Centre régional pour l'eau potable et l'assainissement à faible coût
TAG	Technical Advisory Group
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit (Latrine)

List of Symbols

A	cross-sectional area [m^2]	r_0	pipe radius [m]
D	pipe diameter [m]	**Re**	Reynolds number [-]
f	wall friction factor [-]	T_a	ambient air temperature [K]
g	aceleration due to gravity [m/s^2]	T_s	air temperature in ventpipe [K]
h_D	thermally induced draft [m]	**V**	velocity [m/s]
h_f	flow losses [m]	V_{cl}	centreline velocity [m/s]
H	ventpipe height [m]	**z**	elevation [m]
K	component loss coefficient [-]	α	screen porosity [-]
L	pipe length [m]	β	coefficient for screen loss [-]
p	pressure [kPa]	ν	kinematic viscosity [m^2/s]
p_a	pressure [kPa]	ρ	density [kg/m^3]
r	radial distance from pipe wall [m]		

Chapter One

Introduction

The development of the ventilated improved pit (VIP) latrine represented a great step forward in the state of sanitation in much of the developing world. The VIP latrine is now one of the basic sanitation technologies in use throughout the developing world. However successful the VIP latrine seemed at its conception, it now appears that there are problems which need to be addressed. This research project was undertaken as an investigation into the performance of the VIP latrine in an attempt to understand and improve the ventilation of the latrine pit.

The field investigation portion of the project was completed in Ouagadougou, Burkina Faso. Although every country is unique, Burkina Faso has many characteristics common to many developing countries.

1.1 Burkina Faso: A Profile

Burkina Faso is a small landlocked country of 274 thousand square kilometres in central West Africa (see Figure 1.1). The population of 9.5 million (1992 estimate) is unevenly

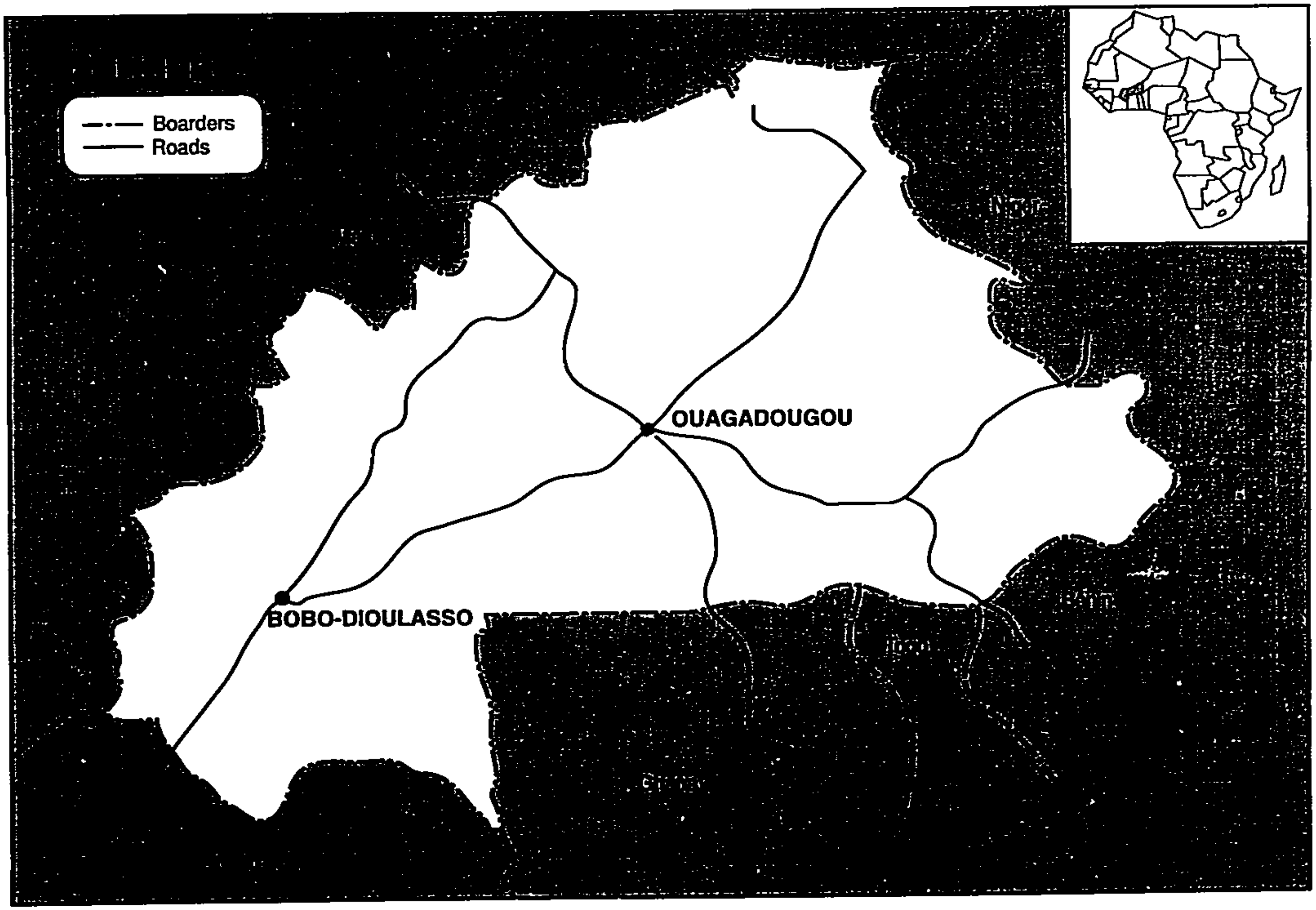


Figure 1.1 Map of Burkina Faso

distributed with the bulk of the population concentrated in the southern and western regions of the country. It is estimated that approximately 9 per cent of the population live in urban centres, the largest of which are Ouagadougou 448 000 and Bobo Dioulasso 273 000. (The data found in the section are condensed from the 1993/94 Economist Country Profile for Burkina Faso)

The country is on the northern boundary of the tropical climate zone near the Sahara and is thus quite arid. A pronounced dry season is evident, with almost no precipitation falling between October and April. The temperature ranges between 26-45 °C in the hottest month of April and between 16-33 °C in the coldest month of January.

The economy of Burkina Faso is based on the export of cash crops and minerals. In 1989 the largest export, cotton, accounted for 47 per cent of exports. Other goods exported are gold (23%), hides and skins (9%) and live animals (6%). Burkina Faso relies heavily on imports for manufactured goods, foodstuffs, chemicals, petroleum and heavy equipment. In 1989 Burkina Faso had a trade deficit of $US 275 million.

Burkina Faso is a member of the Communauté financière africaine (CFA), a group of former French colonies of West Africa which shares a common currency, the franc CFA. The exchange value of the franc CFA is guaranteed by France and its value is tied to the French franc. From its inception until 1993 the exchange rate was set at 50 francs CFA to the French franc. On January 12, 1994 the franc CFA was devalued to 100 franc CFA to the French franc. The exchange rate at the time of writing is 345 francs CFA to the Canadian dollar. It was hoped that the devaluation would encourage exports and aid in alleviating the trade deficit.

Health statistics show that Burkina Faso suffers from several malnutrition-related diseases in addition to onchocerciasis (river blindness), trypanosomiasis (sleeping sickness), malaria, guinea worm and schistosomiasis. The infant mortality rate was 135 per thousand live births in 1991, and average life expectancy was estimated to be 48 years. Only 20 per cent of Burkinabé were estimated to have access to safe drinking water.

These statistics show that Burkina Faso is ideally suited for the use of VIP latrines. The scarcity of water and financial resources preclude the use of an expensive water borne sanitation technology. Many diseases endemic to Burkina Faso could be reduced or even eliminated with the development of a country-wide latrine installation programme.

The improvement of sanitation is one of the aims of le Centre régional pour l'eau potable et l'assainissement à faible coût (CREPA). CREPA is an inter-state centre founded in 1989 by the governments of fourteen francophone countries of the West African Sahel. The major donors supporting the activities of CREPA are the Canadian and Swiss international development agencies. The centre is dedicated to developing and popularizing low cost technologies for water supply and sanitation suitable for the conditions which prevail in the sub-Saharan regions of West Africa.

Although this research focuses on improving the VIP latrine in Burkina Faso, the problems experienced there are common throughout the developing world. The solutions found will therefore have worldwide application.

1.2 Sanitation and Disease

The suffering caused by diseases related to poor hygiene and sanitation is enormous. Thousands of children die daily from dehydration due to diarrhoeal diseases. Helminthic, or worm infections, contribute to malnutrition through nutrient deprivation, and cause joint stiffness and limb swelling (elephantiasis) and even blindness (onchocerciasis). The reduced capacity for work caused by sickness and debilitation greatly reduces productivity, thus exacerbating a community's poverty.

The majority of the diseases causing the greatest human suffering worldwide is preventable, as the pathways by which most infectious diseases are spread are well understood. The rate of infection of a disease can be greatly reduced once the transmission cycle is identified and steps are taken to interrupt this cycle. An understanding of disease transmission mechanisms is, therefore, essential to the engineer designing sanitation equipment for the developing world.

1.3 Pathogen Transmission Cycles

Human excreta can contain many dangerous pathogens, organisms capable of causing disease in humans. A wide variety of infectious diseases, including bacterial, viral and protozoal infections, depend, at least in part, for their transmission on the inadvertent ingestion of pathogens originating in the excreta of an infected person by another member of the community. This is known as the oral-faecal transmission cycle.

Transmission can occur through direct contact with infected faeces or by ingesting food or water contaminated with infected faeces. Some diseases commonly transmitted through this cycle are cholera, typhoid, hepatitis and bacillary and amoebic dysentery. Other diseases, notably helminthic infections, require a maturation period in the soil (roundworm), an intermediate host such as swine and beef (tapeworm), or aquatic snails (schistosome). These infections are then transmitted by contact with infected soil or water, or by ingestion of infected meat.

Whether the primary transmission mode is the direct oral-faecal route or a more indirect cycle, it is clear that the sanitary disposal of human waste plays an important role in the control of these diseases. Tropical hygiene specialists believe that the correct disposal of excreta is one of the most effective measures any community can undertake to improve its health (Feachem 1978). Despite the importance of sanitation, many people in the developing world live without even minimal sanitation facilities. In 1980 the United Nations Development Programme estimated that in less-developed countries, 54 per cent of the population lacked adequate excreta disposal facilities. The situation was somewhat worse in the rural areas where 63 per cent of the population were without sanitation. The United Nations declared the years 1981 to 1990 the Drinking Water Supply and Sanitation Decade. Much effort was expended toward overcoming the technical and economic barriers preventing universal availability of safe water and sanitation. After the Decade there was some improvement in the statistics: it was estimated that only 44 per cent of the total population lacked sanitation facilities. However it was found that even after the efforts of the Water Decade, 51 per cent of the rural population are still without adequate means of excreta disposal (Carter et al 1993). It is clear, therefore, that much work remains to be done to achieve the Decade goal of safe water and sanitation for all.

The importance of sanitary improvements as part of a wider development effort has been identified by many development workers. In the past, great effort and expense have been centred solely on the improvement of water supply without sanitation. As early as 1978, studies, such as an in-depth investigation of water supply in Lesotho, had concluded that water improvements must be accompanied by improved sanitation for significant benefits to be realized (Feachem et al 1978).

1.4 Development of the VIP Latrine

Improvement of sanitation facilities is a priority for many engineers involved in development work. Experience has shown that improved water supply without corresponding improvements in sanitation is not successful in breaking water-borne disease cycles. Low-water-use sanitation is of particular interest because it is appropriate for use in some of the poorest and most disease-ridden areas in the developing world, where water supply is limited.

When considering sanitation systems, sanitary engineers quickly realized that the technology used in developed countries- flush toilets connected to full sewer systems- was inappropriate for use in the developing world. High costs and lack of skilled maintenance workers make full sewerage systems impossible for low-income urban areas. Lack of sufficient water in rural areas often precludes any water-borne sanitation system, such as septic tanks. Engineers began searching for appropriate alternatives, especially for use in arid regions.

In the late 1970's work began on improvements to the pit latrine; one of the oldest sanitation techniques. Unimproved pit latrines consist of a hole dug or bored, covered with a cement or wood cap. A squatting hole in the cap allows for addition of excreta to the pit and a superstructure is built above the cap for privacy. The latrine is used for two to three years until the pit is almost full, at which point it is filled with earth and a new pit is brought into service. After two years the pathogens have died and the excreta is an inoffensive humus. The closed pit can be re-excavated and the contents used as fertilizer. This model is common in Southeast Asia. However, societal attitudes toward the reuse of faeces make this practice rare in Africa.

By isolating and containing human wastes, pit latrines should aid in breaking disease cycles. However, problems have prevented them from becoming fully effective.

Conventional pit latrines have suffered from three major problems: pit collapses, offensive odours and excessive fly breeding. The odours and flies made the latrines extremely unpleasant and occasional pit collapses increased the population's fear of using the latrine. This resulted in a return to open bush defecation in many communities. Numerous flies spread pathogens from excreta in the pit and added to the unpleasantness of the latrine. Together, these problems negated many of the advantages of the latrine.

The Ventilated Improved Pit (VIP) latrine, shown in Figure 1.2, is an attempt to overcome the problems of the conventional pit latrine. Standardized digging practices and prefabricated reinforced concrete caps have enhanced their reliability and greatly reduced the number of pit collapses.

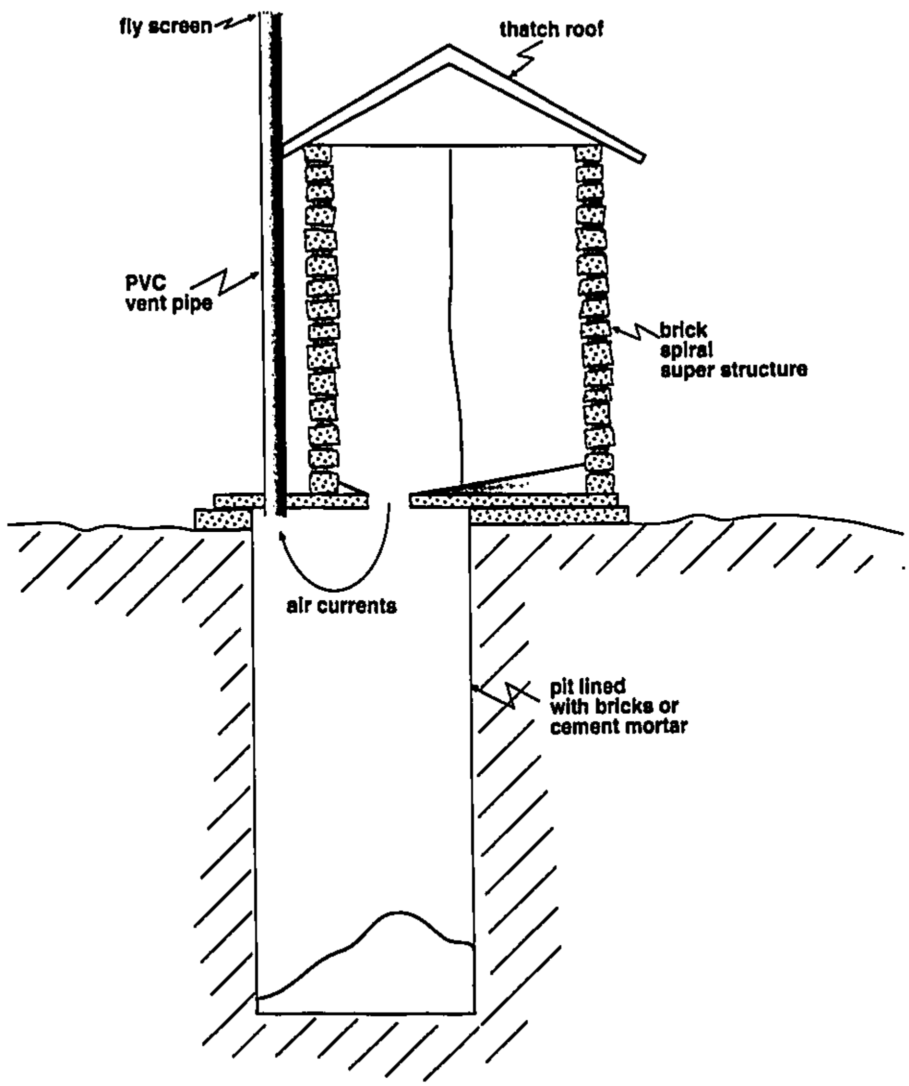


Figure 1.2 VIP Latrine Schematic

A ventilation pipe was added to the pit to reduce the odour and fly problem; wind action on the top of the vent and convection due to solar heating of the pipe cause an updraught in the pipe, venting the odours and drawing air down through the squat-hole. Flies attracted to the odours are prevented from entering the top of the pipe by a screen. A few flies will enter by the squat-hole and lay eggs in the latrine pit but the young, attracted by the light, will fly up the pipe and be trapped by the screen. Thus, as well as being more pleasant to use than conventional pit latrines, VIP latrines control the transmission of disease more effectively by preventing the escape of flies contaminated with waste in the pit.

Unfortunately, the VIP latrine was developed in an empirical manner; little analytical work was carried out in the initial design stage. Many configurations were tried and the basic design was arrived at by trial and error. Some field investigations were undertaken (Ryan and Mara 1982, Ryan and Mara 1983), but these studies were quite limited and have not been widely verified by further work. Initially, the results were encouraging but now that VIP latrines have been in service for ten years in some areas, reports of poor performance are surfacing (UNICEF 1983, Goss 1991). Field reports have shown that in some instances, VIP latrines are not well ventilated and the odour and excessive fly breeding problems of conventional pit latrines are still occurring. With little theoretical understanding of the ventilation process and limited empirical data, these problems are difficult to solve.

At its introduction, the VIP latrine was seen as a great advance in rural sanitation, and in the past fifteen years, thousands of these units have been installed throughout Africa. Despite the number of latrines in existence, recent reports of unsatisfactory ventilation of some VIP latrines continue to be received, as noted below.

> The VIP latrine should not be constructed. As odour and fly control was found to be no more effective in VIP latrines, and the ventpipes of a high proportion of VIPs were not operating efficiently, it was concluded that the VIP latrine is not the most appropriate for many of the possible latrine sites. (Goss, 1991)

> The design of the VIP latrine was intended specifically to eliminate smell and fly nuisance. Yet smell was the major reason for the rejection of this type of latrine. (UNICEF, 1983)

The VIP latrine is one of the lowest cost sanitation options and is particularly well suited to remote and arid areas with high levels of endemic infection of faecally transmitted diseases. In many cases it is the only option economically feasible for a community, and then often only with outside assistance. It is, therefore, important that the VIP latrine operate well and be sufficiently appealing in order that it will be accepted and used by the entire population. If even a small portion of the population reverts to traditional unsafe defecation practices due to unpleasant and malodorous latrines, much of the disease protection provided by the latrines will be lost. Finding solutions to the odour and fly breeding problems now becoming apparent in the VIP latrine should be a priority with engineers concerned with low-cost sanitation options for the developing world.

1.5 Improving the VIP Latrine

Since the World Bank-sponsored work carried out in the first half of the United Nations Water and Sanitation Decade (Ryan and Mara 1982, Ryan and Mara 1983, Mara 1984), no rigorous investigation of the VIP latrine has been undertaken. Anecdotal reports of VIP performance have been hard to assess and problems are difficult to resolve due to a lack of data.

The reported problems have centred around an odour and fly breeding problem in certain VIP latrines. Both of these can, in many cases, be caused by an insufficient rate of ventilation through the pit vent pipe. When the pit is not well ventilated odours will exit the pit through the squat hole into the latrine superstructure. Then the latrine will be unpleasant to use and will attract a great number of flies.

If ventilation rates can be improved, it is possible that many of the reported problems will then be rectified. It is with this aim that the present study was undertaken.

Previous work (Ryan and Mara 1982) indicates that the dominant mechanism driving pit ventilation is the action of the wind across the top of the vent pipe. Upward convection caused by solar heating of the vent pipe contributes only negligibly to the total updraught. Therefore, attention was concentrated on improving the ventilation caused by the wind. The UNDP TAG concentrated its work on the questions of the optimal ventpipe diameter and height and on latrine superstructure orientation with respect to the prevailing wind. This project looked at a new possibility for improving the ventilation rate.

The present VIP design specifies a bare vent pipe outlet, the pipe being merely covered with a fly screen. It is possible however to replace this bare outlet with fittings that will modify the air flow around the pipe outlet and thus enhance the suction under which air is drawn out of the vent pipe.

When considering possible ventpipe outlet accessory designs, it was important to keep in mind the conditions under which they will ultimately be built and operated. VIP latrines are generally built by semiskilled workers trained in latrine construction. This precludes the use of any accessory of complex design or which is difficult to fabricate. To enable the latrine to be built easily and at low cost, the accessories must be made of inexpensive, easily obtainable materials. Also, the accessories must be able to operate under extremes of temperature and humidity with no maintenance. This means that no designs with moving parts could be considered.

The above criteria (simple, low-cost, no moving parts) eliminated some designs which had seemed promising. Any rotating device such as spinning rooftop vents or vents with wind vanes to align them with the wind cannot be expected to operate for long under harsh conditions. This lead to the conclusion that any fitting considered must be effective regardless of the wind direction. This reasoning lead to the design possibilities which were tested.

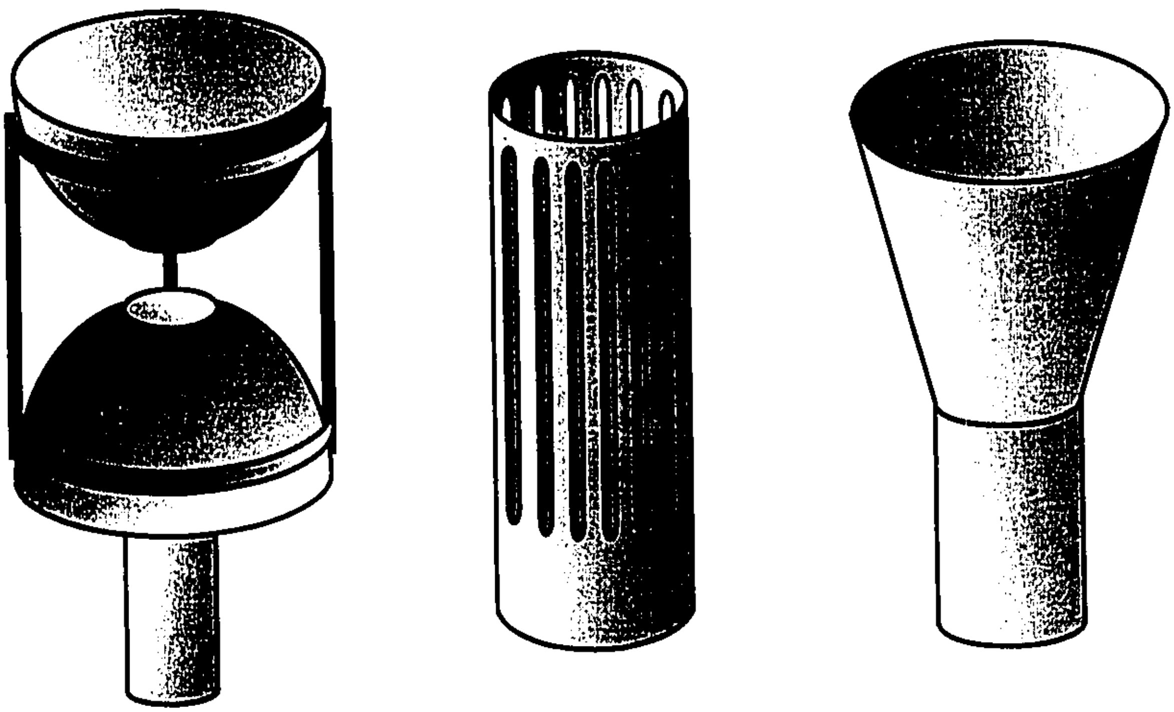


Figure 1.3 Venturi, Slotted and Divergent Accessories

The three possible outlet designs shown in Figure 1.3 were tested to determine their effectiveness in increasing the ventilation rate through the ventpipe. The venturi and slotted fittings were tested in the laboratory and then all three fitting types were tested in the field on actual VIP latrines. One outlet modification takes advantage of the venturi effect, by which the pressure of a moving fluid is reduced as the velocity increases. If an outlet is designed so that the wind is forced through a restricted area, the air velocity will necessarily increase and the pressure above the pipe exit will decrease, thus strengthening the driving force creating pit ventilation. The second fitting increases the swirling turbulent eddies of the wind above the pipe exit by passing it through vertical slots in the pipe sides. The third possibility tested was a divergent fitting which flares the end of the pipe to a diameter greater than that of the pipe. It has been theorized by some designers that the resulting greater surface area over which the wind is acting will produce a greater ventilation flow.

The project was undertaken with the support of the Canadian International Development Agency (CIDA) through the Grants for Canadians programme. The initial laboratory tests were conducted in Canada at the University of Ottawa. The field work was completed in Ouagadougou, Burkina Faso with the collaboration of CREPA between November 1993 and August 1994.

In summary, the objectives of the project were:

- to improve the understanding of VIP latrine ventilation mechanisms
- to observe VIP latrine operation on-site in Africa
- to determine which accessories are capable of increasing the ventilation rate through the VIP latrine

•to determine under what conditions the accessories will produce ventilation increases

This research paper describes one attempt to enhance disease control and thus alleviate some of the suffering in the developing world through the improvement of one of the basic sanitation technologies: the VIP latrine.

Chapter Two

Literature Review

2.1 Development of the VIP Latrine

During the 1950's, at the beginning of the western aid effort to the developing world, little effort was focused on creating specialized technology for use in developing countries. It was assumed that practices and technology common in the developed world could be transferred directly for use in the developing world. Thus, little research was directed toward addressing the sanitation problem in the developing world.

It became apparent, however, that the climatic, social and economic conditions prevalent in many tropical countries make demands on machinery and systems that had not been foreseen in their designs. The relatively rapid failure of many installations caused a reassessment of the use of western technology in developing countries. In the 1970's, western engineers began to develop technology specifically for use in the harsher environment of the tropics. Much of their effort was expended in developing water supply technology, as this was seen as the most pressing need. So, while new pumps and distribution networks were developed, sanitation technology remained largely unimproved.

As water supplies improved in developing countries it was observed that the health of the population did not improve to the extent expected. An extensive study carried out in Lesotho in the mid-1970's showed that water supply improvement without concurrent improvements in sanitation had little effect toward improving a community's health (Feachem et al 1978). This finding spurred renewed interest in the development of sanitation technologies suitable for use in developing countries.

Particularly important was the development of low water use on-site sanitation technology. It was at this point that the potential of pit latrines began to be reassessed since they are suitable for use in remote and low-income areas. The major problems of the conventional pit latrine- odour, fly nuisance and pit collapses -were addressed by Blair Research Laboratories in Zimbabwe. It was here that the VIP latrine was developed (Morgan 1976). The addition of the vent pipe reduced the odour and fly problems and standardized building practices with reinforced concrete pit cover slabs reduced the incidence of pit collapse.

During the United Nations Drinking Water and Sanitation Decade (1981-1990), much attention was given to developing solutions to address the problems of sanitation in the developing world. In particular, the ventilated improved pit latrine received much attention in an effort to understand the ventilation mechanisms and to specify the most efficient ventpipe sizes.

The United Nations Development Programme established a Technical Advisory Group (TAG) in 1982, with the aim of developing and implementing lowcost sanitation technologies. This group investigated the ventilation of VIP latrines and published six technical notes on aspects of VIP ventilation and design (Morgan & Mara 1982, Ryan & Mara 1982, van Nostrand & Wilson 1982, Ryan & Mara 1983, van Nostrand & Wilson 1983, Mara 1984).

The TAG investigated the ventilation of VIP latrines and specified recommended ventpipe diameters and heights. In addition, the group looked at the effect of the orientation of the ventpipe and the latrine superstructure with respect to the prevailing wind. The result of the TAG reports was a series of design recommendations and a set of standardized plans which have been incorporated into many publications intended to popularize the VIP latrine (Kalbermatten et al 1980, Lochery & Adu-Asah 1985, Jeeyaseelan & Lohani 1987, Winblad & Kilama 1988, CREPA 1992, Franceys et al 1992, Morgan 1993). Since the World Bank publications of the 1980's, thousands of VIP latrines have been installed throughout Africa and in other areas of the developing world.

The TAG publications included recommendations for methodology for the further investigation of VIP latrine ventilation. However, since the publication of the World Bank investigations, no further work has been published on VIP ventilation.

The operation of VIP latrine installations in the twenty years since their introduction has not been a complete success. Reports of unacceptable odour and fly problems have appeared (UNICEF 1982, Ativon & Hereau 1986) and some organisations have even suggested discontinuing VIP installation (Goss 1991). Despite these problems, it appears that little work has been done to improve the VIP latrine since its initial design.

2.2 Natural Ventilation

Natural ventilation takes advantage of the driving forces of the wind and density differences between internal and external air to affect air change in a building without mechanical air-moving devices. This principle has been known for thousands of years and has been incorporated into the design of ancient buildings. In fact, there are examples from the natural world of termites and bees constructing colonies which incorporate structures to control natural ventilation (Croome & Roberts 1981).

Due to the significant energy costs incurred through mechanical ventilation, much research has been done on natural ventilation, particularly its industrial applications. Therefore, the movement of air within factory buildings and its control through the use of roof vents, vent hoods and wall louvres is well understood. Standard textbooks and manuals exist to aid in applying the principles of natural ventilation and mechanically aided natural ventilation (ASHRAE 1981, Baturin 1972, Croome & Roberts 1981).

The ASHRAE Handbook (ASHRAE 1981) suggests a list of rules to be observed when designing a natural ventilation system. These include:

1. Systems using natural ventilation should be designed to be effective regardless of wind direction

2. Inlet openings should not be obstructed by buildings, trees etc.

3. Greatest flow per unit area is obtained by using inlets and outlets of nearly equal area

4. There must be a vertical difference between inlet and outlet for temperature difference to produce natural ventilation

5. When both wind and buoyant forces act together, resulting airflow is not equal to the two flows estimated separately but is proportional to the square root of the sum of the squares of the pressure differences

Many of these rules have been taken into account in the design of the VIP latrine. The design recommendations of the UNDP Technical Advisory Group include ventpipe height and diameter specifications in line with rules 3 and 4 and call for the placement of the latrine so that it will be unobstructed and open to the wind regardless of direction (Mara 1984, Ryan & Mara 1983).

Much of the literature on natural ventilation arises from the applications to industries such as smelting and rolling which involve large buildings with significant temperature differences. Therefore many of the ventilation control features are not directly applicable to VIP latrine ventilation in which the scale and temperature differences are markedly smaller. However, like many applications of technology in the developing world, attention is now returning to ancient applications of natural ventilation. Many of these have more in common with the ventilation of VIP latrines.

One such technology is the solar chimney. This is a chimney designed to collect solar radiation which then produces buoyancy driven ventilation of the building to which the chimney is attached. Studies have been made in India (Bansal et al 1994) of natural ventilation systems involving a wind catching tower which diverts air into the building and solar chimneys to aid in air extraction. Chimneys are slanted to expose more surface directly to the sun and are covered in black solar absorbing plates on the sunny side and insulation on the shaded side. It was estimated that the solar chimney effect was relatively larger at lower wind speeds.

A similar solar-chimney based ventilation system was investigated in Nigeria (Barozzi et al 1992) using both numerical and experimental studies. The system included a raised central roof chimney running the length of the building. It was concluded that the solar chimney aided ventilation flows more than a regular roof vent.

Modelling of natural ventilation in agricultural buildings (Zhang et al 1989) has shown that at low wind speeds, buoyancy-driven ventilation was predominant but became less significant as the wind speed increased. It was found that as wind speed increased, the ventilation caused by the wind increased linearly while ventilation caused by buoyancy dropped off slowly with increasing wind speed. Both these tendencies reduce the relative importance of buoyancy driven ventilation at higher wind speeds.

The findings of Bansal and Zhang agree well with the conclusions reached by the UNDP TAG with respect to the importance of buoyancy-driven ventilation. As it is designed now, the VIP latrine ventpipe is a poor solar chimney. Excessive cost precludes improving its ability to absorb solar radiation through the use of special materials or glazes. Space constraints make it difficult to slant the chimney to allow greater exposure of the pipe surface to the sun. This leads to the conclusion that the ventilation of the VIP latrine relies almost exclusively on wind driven ventilation. Therefore, attempts to improve ventilation would best be centred on improving the wind effect on the VIP latrine ventpipe.

2.3 Socio-Cultural Aspects

The early experience of development workers quickly showed the primary importance of societal and cultural influences on the success or failure of water supply and sanitation programmes in the developing world. Some installations which appeared to be technically sound did not perform effectively for reasons that were not clear at the time. This sparked interest in the nontechnical aspects of development projects which, it was becoming clear, greatly affected their impact.

The Water Decade provided an opportunity for extensive investigation into these social aspects, and spawned many studies which were published in the early 1980's (Elmendorf & Buckles 1980, Perret 1983, Bourne 1984, White 1992). The United Nations TAG, besides technical investigations into VIP latrines, published several working papers with the aim of promoting community involvement in sanitation projects (Perret 1982, Simpson-Herbert 1983, Perret 1984, Cross 1985). Many of these papers are devoted to gathering socioeconomic data for sanitation projects and techniques for involving the community in project evaluations. This reflects the relatively recent appreciation of the importance of community involvement in the planning of successful projects. In particular, the importance of the participation of women in community-based development projects began to be appreciated (Perret 1985).

Recent workers have realized that to be successful it is important that a wide multi-disciplinary approach be taken to the planning of water supply and sanitation programmes. Thus, greater emphasis is now being placed on the so-called software aspects of the projects, such as community health and hygiene education and the involvement of community-level organisations. Typical of this approach is the successful latrine program in Lesotho, which put much effort into community involvement and education (UNDP 1994, Blackett 1994).

With this emphasis in mind, an effort was made during this project to examine the problem of VIP latrine ventilation from all points of view; technical, economic and sociological.

Chapter Three

Theoretical Analysis

3.1 Governing Equations

As with all fluid mechanics phenomena, the flow of air in the vent pipe of the VIP latrine is governed by two fundamental principles: the conservation of energy and the conservation of mass. For the analysis of ventilation within the VIP latrine, the geometry and flow conditions are such that several assumptions are justified, allowing for the use of simplified mathematical expressions of the two conservation principles. For use in the analysis of pipe flow such as that in VIP latrine ventilation, it is reasonable to use the one-dimensional approximation by which variations in fluid properties, such as velocity and pressure, across the pipe section are neglected and the average property at a point in the pipe is used. Thus, only variations in the direction of flow are considered. The flow is also considered to be steady in time, allowing all time derivatives to drop out of the equations. The resulting equation is the familiar Bernoulli equation. If an expression for losses is incorporated into the Bernoulli equation the result is the steady state one-dimensional energy equation. Expressed between two points in the pipe, this equation is of the form given in equation 3.1

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_{f_{1\,2}} \qquad 3.1$$

where $h_{f1\text{-}2}$ = energy losses from point 1 to 2

For the particular case of flow within the ventpipe of the VIP latrine, the elevation terms in equation 3.1 are not required. This is because the flowing fluid (air) is also the continuum surrounding the latrine. Thus, any potential energy gained by the rising fluid is offset by an equal loss of potential of the surrounding air moving into the pit through the squat hole. Therefore, the appropriate form of the Bernoulli equation for the analysis of VIP latrine ventilation is:

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + h_{f_{1\,2}} \qquad 3.2$$

The continuity equation is an expression of the conservation of mass. The same simplifications of steady-state and one dimensionality that were used above can be applied, as well as the assumption of incompressibility of the fluid. The result is the simplified form of the continuity equation given in equation 3.2

$$V_1 A_1 = V_2 A_2 \qquad 3.3$$

Equations 3.2 and 3.3 can be used to understand the driving force behind the ventilation of the VIP latrine.

Consider two points, one in the latrine pit just outside the inlet of the vent pipe (*1) and the other at the ventpipe outlet (*2). Writing Equation 3.2 between these two points gives:

$$p_1 + \frac{\rho V_1^2}{2} = p_2 + \frac{\rho V_2^2}{2} + \rho g h_{f_{1\,2}} \qquad 3.4$$

$$\Delta p_{1\text{-}2} = \frac{\rho (V_2^2 - V_1^2)}{2} + \rho g h_{f_{1\,2}} \qquad 3.5$$

V_2 is the air velocity in the ventpipe. Since (*1) is in the pit, where the air is essentially quiescent, V_1 is negligible, so that:

$$\Delta p_{1\text{-}2} = \frac{\rho V_2^2}{2} + \rho g h_{f_{1\,2}} \qquad 3.6$$

The pressure difference (Δp_{1-2}) in equation 3.6 drives the ventilation. This pressure difference is the difference between atmospheric pressure in the pit and the pressure at the pipe outlet. It can be seen, again using the Bernoulli equation, that this pressure difference is a function of the wind speed (V_w).

$$\Delta p_{1-2} = \frac{\rho V_w^2}{2} \qquad 3.7$$

Combining equations 3.6 and 3.7 gives:

$$\frac{\rho V_w^2}{2} = \frac{\rho V_2^2}{2} + \rho g h_{f_{1\,2}} \qquad 3.8$$

Equation 3.8 can be used, with appropriate approximations for the losses (h_f), to estimate the venting velocity to be expected for a given wind speed. The losses can be expressed as:

$$h_f = (\Sigma K + f \frac{L}{D}) \frac{V_2^2}{2g} \qquad 3.9$$

The minor losses (ΣK) consist only of the inlet loss:

$$\Sigma K = K_{inlet}$$

$$\Sigma K = 0.5$$

For the VIP latrines under consideration L=3m and D=0.2m. Using these values and combining equations 3.8 and 3.9 gives:

$$V_2 = \sqrt{\frac{V_w^2}{15f + 1.5}} \tag{3.10}$$

The friction factor (f) can be determined using the Moody diagram. Since the Moody diagram requires the Reynolds number, it will be necessary to iterate to find the solution for equation 3.10. For example, using a wind velocity of V_w=3 m/s and assuming a "smooth" pipe for the use of the Moody diagram, a value of V_2= 2.2 m/s is calculated. This is somewhat higher than the average ventpipe velocity of 0.9 m/s for a wind speed of 3 m/s which was observed in the field units with no accessories. However, when a loss coefficient for the flyscreen is incorporated into equation 3.10 (see Section 3.2.1 for details of this procedure), the predicted velocity is reduced to 1.4 m/s, which is closer to the observed velocity.

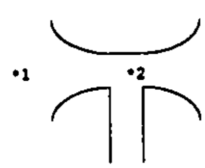
Equation 3.10 shows that the greater the wind speed above the pipe exit the greater the ventpipe velocity will be. If a wind exists in the open air flow, and the air in the pit is quiescent, then, due to this increased wind velocity at the top of the pipe, the pressure in the open air flow will be lower than it is in the pit. This pressure difference results in a net force imbalance which draws air out of the pipe. Continuity demands that the volume of air leaving the pipe is balanced by an equal inflow. Thus, the wind action at the top of the vent pipe draws air out, which is replaced by air drawn up from the latrine pit.

In addition to the pressure difference driving the flow of air, there will be a certain amount of turbulent entrainment of air from the pipe outlet. This effect occurs wherever two layers of fluid moving at different speeds come into contact. The friction produced between the two layers causes the formation of turbulent eddies which tend to entrain fluid from the slower moving layer into the faster moving layer.

3.1.1 Venturi Fitting

The venturi fitting is an accessory formed from two bowls, one sitting inverted over the pipe outlet and the other held upright at a distance above the outlet (see Figure 4.1). The lower bowl has a hole allowing air to flow out of the vent pipe.

Theoretically, the venturi fitting should increase the flow of air up the vent pipe by increasing the effective wind velocity above the pipe outlet. The fitting acts essentially like a reducer in a duct: the dome contours of the bowls force the wind through the restricted area between the two bowls, whatever the direction from which the wind is approaching.



Rearranging Equation 3.2 gives:

$$p_1 - p_2 = \frac{\rho\,(V_2^2 - V_1^2)}{2} + \rho g h_{f_{1\,2}} \qquad 3.11$$

From Equation 3.3:

$$V_2 = V_1 \frac{A_1}{A_2} \qquad 3.12$$

$$V_2^2 = V_1^2 \left(\frac{A_1}{A_2}\right)^2 \qquad 3.13$$

Substituting into equation 3.11 gives:

$$\Delta p_{(1\text{-}2)} = \frac{\rho V_1^2}{2}\left[\left(\frac{A_1}{A_2}\right)^2 - 1\right] + \rho g h_f \qquad 3.14$$

Since it is not possible to define the area ratio (A_1/A_2) used above, equation 3.14 cannot be used to determine p_2. However, equation 3.14 does provide a qualitative demonstration of the effect of the venturi fitting. Because of the configuration of the fitting, the area ratio is greater than one, so that the term in brackets in equation 3.14 is positive. Provided that the frictional losses (h_f) are not large, this results in a non-zero $\Delta p_{1\text{-}2}$, i.e. p_2 is lower than p_1. That is, the pressure at the top of the pipe is less than the pressure in the free flowing wind. So the presence of a venturi device will induce greater flow out of the ventilation pipe than the straight pipe.

However, Equation 3.14 shows that there is a factor, frictional losses, which reduces the venturi effectiveness. Whenever a free flowing fluid encounters a solid surface, a boundary layer will form. The boundary layer is the thickness of fluid which has been slowed by viscous forces due to the solid-fluid interface. This thickness grows as the flow advances along the surface. If it continues long enough, the boundary layer may become turbulent and detach from the surface, creating pockets of stagnant or recirculating fluid. If the upper and lower bowls of the venturi were sufficiently close that the boundary layers from the upper and lower bowls interfere with each other, the result could be that the losses become significant and the net benefit of the venturi is lessened.

As the bowls are brought increasingly close together, the frictional losses will increase as the boundary layers formed on the bowl surfaces will occupy a greater portion of the space between the two bowls. Simultaneously the venturi effect is increased as the air is forced through an increasingly smaller area. The optimal point at which the net result of these two effects produces a maximum ventilation flow must be determined through experimentation.

3.1.2 Slotted Fitting

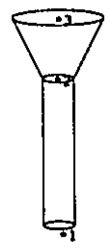
The slotted fitting consists of a section of pipe just below the pipe outlet in which vertical slots have been cut around the circumference (see Figure 4.2). The slots occupy approximately half the surface area of the pipe.

The slots in the fitting increase the turbulence in the wind stream passing over the pipe outlet as eddies form in the wakes of the bars between the slots. As the air is forced to flow around each slot, a wake will form behind it, above the ventpipe outlet. Wakes are regions of swirling turbulent eddies and low pressure. These eddies, and the low pressure of the wake region, contribute to the mixing of fluid in the pipe and the wind, thus increasing the entrainment of ventilated air into the wind stream.

However there will be increased frictional losses due to the air passing through the narrow slots. Due to the complex nature of the turbulent flow it is impossible to predict from purely theoretical concepts whether the increased mixing will be large enough to overcome the additional losses for any given configuration of slots in the pipe.

3.1.3 Divergent Fitting

The divergent fitting is a flared accessory which expands from the pipe diameter to a larger diameter. It acts essentially like a diffuser opening to a free discharge. To analyze the effect of the divergent fitting, it is necessary to compare the flow through the straight pipe (analyzed in Section 3.1) to that through the divergent fitting.



Applying equation 3.2 between (*1) and (*2) with V_1=0, gives::

$$p_1 - p_2 = \frac{\rho V_2^2}{2} + \rho g h_{f_{12}} \tag{3.15}$$

Applying equation 3.2 between (*2) and (*3) gives:

$$p_2 - p_3 = \frac{\rho(V_3^2 - V_2^2)}{2} + \rho g h_{f_{23}} \tag{3.16}$$

Adding equations 3.15 and 3.16 gives:

$$\Delta p_{1\text{-}3} = \frac{\rho V_3^2}{2} + \rho g (h_{f_{12}} + h_{f_{23}}) \tag{3.17}$$

From continuity:

$$V_3^2 = \left(\frac{A_2}{A_3}\right)^2 V_2^2 \qquad 3.18$$

So equation 3.17 becomes:

$$\Delta p_{1\text{-}3} = \left(\frac{A_2}{A_3}\right)^2 \frac{\rho V_2^2}{2} + \rho g\left(h_{f_{1\,2}} + h_{f_{2\,3}}\right) \qquad 3.19$$

Losses can be expressed as:

$$h_{f_{1\,2}} = \left(\Sigma K_{1\text{-}2} + f\,\frac{L}{D}\right)\frac{V_2^2}{2g} \qquad 3.20$$

The minor losses are:

$$\Sigma K_{1\text{-}2} = K_{inlet}$$

$$\Sigma K_{1\text{-}2} = 0.5$$

Using the same values as in Section 3.1 (L=3m and D=0.2m), the total losses between (*1) and (*2) are then:

$$h_{f_{1\,2}} = (0.5 + 15f)\,\frac{V_2^2}{2g} \qquad 3.21$$

The losses between (*2) and (*3) are simply the diffuser losses:

$$h_{f_{2\,3}} = K_{diffuser} \frac{V_2^2}{2g} \qquad 3.22$$

Again, the pressure difference between the pit and the pipe outlet ($\Delta p_{1\text{-}3}$) is a function of wind speed:

$$\Delta p_{1\text{-}3} = \frac{\rho V_w^2}{2} \qquad 3.23$$

Substituting equations 3.21, 3.22 and 3.23 into equation 3.19 and simplifying gives:

$$V_2 = \sqrt{\frac{V_w^2}{\left(\frac{A_2}{A_3}\right)^2 + 15f + 0.5 + K_{diffuser}}} \qquad 3.24$$

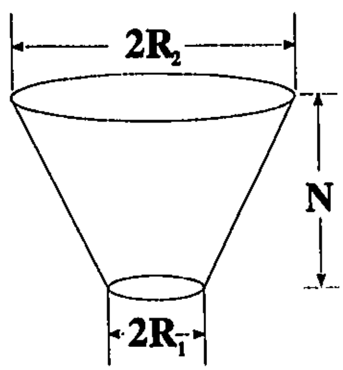
Following Blevins (Blevins 1984), the loss coefficient for a diffuser ($K_{diffuser}$) can be expressed in terms of a static pressure recovery coefficient (C_p):

$$K_{diffuser} = 1 - \left(\frac{A_2}{A_3}\right)^2 - C_p \qquad 3.25$$

So that equation 3.24 becomes:

$$V_2 = \sqrt{\frac{V_w^2}{15f + 1.5 - C_p}} \qquad 3.26$$

Comparing equation 3.26 to equation 3.10, it can be seen that V_2 will be greater for the diffuser arrangement if $C_p > 0$. (This assumes that the friction factor (f) is equal in both cases. While, strictly speaking f is a function of V_2, it is small with respect to the other terms so that the difference in f in the two cases is not significant). Therefore, it can be seen from this idealized theoretical analysis that an improvement in exit velocity with a diffuser is possible. Practically speaking however, the phenomenon here is three-dimensional and turbulent with significant momentum exchange occurring at the top of the diffuser.



The static pressure recovery coefficient (C_p) for a diffuser opening to a free discharge is a function of diffuser geometry, inlet Reynolds number and flow profile. The diffuser performance decreases with decreasing Reynolds number as this condition corresponds to an increased boundary layer thickness (Blevins 1984). Blevins presents figures which can be used to determine C_p for a conical diffuser with inlet Reynolds numbers of greater than 75 $\times 10^3$. These figures are plots of the diffuser performance as a function of area ratio (A_2/A_1 -1) and the nondimensional length (N/R_2).

The figures for C_p presented in Blevins assume a Reynolds number significantly higher than is to be expected for the relatively low wind-induced ventilation typical in VIP latrines. The maximum pipe velocity observed in the field for the divergent fittings was approximately 2 m/s, which corresponds to a Reynolds number of 27×10^3. This lower Reynolds number would mean that a diffuser operating on a VIP latrine would perform less efficiently and produce greater losses than predicted for higher flow velocities.

In summary, this analysis has shown that it is possible to design a diffuser which will theoretically produce ventilation rates greater than those of the straight pipe. However, the loss coefficients presented in the literature (Blevins 1984) correspond to high Reynolds number flow through diffusers opening to quiescent air. The VIP ventpipe is characterised by lower Reynolds number flow with a wind velocity passing over it. These factors significantly lower the diffuser efficiency from the theoretical value. Therefore, it is to be expected that little ventilation increase will be gained for the added cost and fabrication complexity which the addition of a diffuser represents.

The analysis in sections 3.1.1 to 3.1.2 indicated that it should be theoretically possible to improve the rate of ventilation through the vent pipe by the addition of an accessory placed on the outlet of the pipe. Without resulting to complex computational analysis, it was not possible to determine which accessory will produce the greatest ventilation rate increase. This question was examined through the laboratory and field experimentation.

3.2 Natural Convection

Natural or free convection is the movement of fluid resulting from body forces due to density gradients within the fluid. These density differences are caused, in most cases, by temperature differences resulting from heat transfer. Since the forces due to the interaction of density gradients with the gravitational field are small, the resulting velocities are also small. Free convection flow velocities are generally much smaller than those caused by external forcing conditions such as pumps or fans.

Despite the relatively low velocities resulting from free convection, there are many applications in which it plays an important role. These include oceanic and atmospheric circulation, heat transfer from passive heaters and refrigeration coils and natural ventilation. It is in its application to natural ventilation that free convection is relevant to the examination of VIP latrine ventilation.

In the case of VIP latrine ventilation, the free convection velocity is set up as the air within the ventpipe close to the wall is heated by the pipe wall which acts as a solar collector. This temperature effect extends some distance away from the wall as heat is transferred away from the wall into the air in the pipe. Also, as the heated air rises, it entrains quiescent air to form a boundary layer along the tube wall. Throughout this boundary layer both velocity and temperature vary continuously.

3.2.1 Governing Equation of Natural Convection

An exact analysis of the natural convection flow within the ventpipe of the VIP latrine would involve the solution of the fully three-dimensional energy and momentum equations which take into account the variations in velocity and temperature across the pipe diameter. However, as with the analysis of wind-induced flow in section 3.1, it is reasonable to assume constant properties across the pipe. This simplifies the analysis so that one-dimensional equations may be used.

The ventpipe wall, heated due to solar radiation, transfers this heat to the air within the pipe. This results in a higher air temperature within the pipe than in the ambient air. This higher temperature, or temperature surplus, drives the ventilation since the warmer air within the pipe is less dense than the surrounding air. The driving force due to a temperature surplus can be expressed mathematically by the stack effect equation given in many texts on ventilation design (Emerick 1951). This equation, in SI units is:

$$h_D = 2.90\,HP\left(\frac{1}{T_a} - \frac{1}{T_s}\right) \qquad 3.27$$

where

h_D	thermally induced draft [m air]
H	stack height [m]
P	ambient pressure [kPa]
T_a	ambient air temperature [K]
T_s	stack air temperature [K]

Experimental data from the field tests (see section 5.2) shows that almost all the temperature surpluses measured will be less than 5 °C (within three standard deviations of the mean). The temperature readings were taken under flow conditions, when the venting air was removing heat to somewhat lessen the temperature rise of air in the pipe. Therefore, this data will be an underestimate the temperature that would have occurred in quiescent air in the pipe. The draft calculated from this data will then tend to underestimate the thermal driving force under quiescent conditions. However, by using an extreme value for the temperature surplus, this tendency is balanced and the result is a more reasonable estimate of the thermal driving force under flow conditions.

Applying equation 3.26 with an ambient temperature of 30 °C, a temperature surplus of 5 °C, a stack height of 3 m and atmospheric pressure of 101.3 kPa gives a value for the thermally induced draft of:

$$h_D = 4.72 \times 10^{-2} \text{ m}$$

This induced draft (h_D) works to accelerate the quiescent air in the pit to pipe ventilation velocity (V). The draft is countered by the frictional losses in the system (h_f). The sum of the two opposed forces produces the resultant velocity (V).

$$h_D - h_f = \frac{V^2}{2g} \qquad 3.28$$

The losses in the system include minor losses and wall friction losses. It is to be expected that the minor losses will be much greater than the wall friction losses in this situation.

However, since the wall friction loss is straight forward to calculate, it has been included in this analysis. The losses are expressed as:

$$h_f = (\Sigma K + f\frac{L}{D})\frac{V^2}{2g} \qquad 3.29$$

where	K	component loss coefficient
	f	wall friction factor
	L	pipe length
	D	pipe diameter

The minor losses are made up of three components:

$$\Sigma K = K_{inlet} + K_{screen} \qquad 3.30$$

The inlet loss is the typical values of :

$$K_{inlet} = 0.5$$

An estimate for the loss coefficient for the fly screen is given by Blevins (Blevins 1984) as:

$$K_{screen} = \frac{\beta(1-\alpha^2)}{\alpha^2} \qquad 3.31$$

where	α	screen porosity
	β	function of Re based on screen fibre diameter

The porosity can be calculated from:

$$\alpha = \frac{(l - d)^2}{l^2} \qquad 3.32$$

where l spacing between fibres
d fibre diameter

For the typical flyscreens used on VIP latrine l = 3 mm and d = 1 mm. The values for β are given in tabular form as a function of the Reynolds number based on the fibre diameter (Blevins 1984).

The wall friction losses can be estimated using the Moody diagram with pipe length L=3m and pipe diameter D=0.2m. For the calculation it was assumed that the pipe was "smooth".

Since the velocity must be known to calculate (h_f) from equation 3.28, it is necessary to iterate between equations 3.27 and 3.28 until a they converge on a value for V. Using the values listed above to calculate the component loss coefficients, the value for the thermally induced velocity was found to be:

$$V = 0.36 \text{ m/s}$$

This ventpipe velocity is relatively small in comparison with many of the values measured in the field (0.2 m/s to 2.5 m/s). Considering that this value was calculated using a large value of temperature surplus, it is to be expected that for much of the time the thermally induced velocity will be less than this value. Therefore it can be concluded that the thermally induced component of the ventpipe velocity is negligible for most field conditions.

Chapter Four

Laboratory Experimentation

The experimental investigation was divided into two phases: preliminary laboratory model work and a full scale field study. The laboratory work was completed in the hydraulics laboratory at the University of Ottawa before the author's departure for Africa. The field study was undertaken in Ouagadougou, Burkina Faso in cooperation with le Centre régional pour l'eau potable et l'assainissement à faible coût (CREPA).

4.1 Laboratory Methodology

The laboratory work was a preliminary investigation and was therefore intended primarily as a feasibility study for the test equipment being considered for the field work portion of the project. It was intended to eliminate any test apparatus which showed little promise of success in the full scale experiments.

4.1.1 Experimental Apparatus

The tests were conducted using apparatus designed to simulate the ventilation system of a VIP latrine. The latrine ventpipe was simulated with a clear acrylic tube 1.82 metres long with an outer diameter of 152 millimetres and a wall thickness of 6.4 millimetres. The tube was held vertically, secured to a tripod support stand, so that the lower end of the tube was 20 centimetres above the ground. The apparatus was set up in a section of the laboratory shielded from drafts with temporary dividing wall. The floor of this section was cleared to allow for free entry of air into the pipe.

The wind above the ventpipe outlet was simulated by two variable speed fans. The fans were positioned on a stand 2 metres from the tube at a height so that the tips of the lower blades were level with the upper end of the tube. The fans were placed at a distance of 2 metres so that there would be some dampening of the oscillations in the wind speed caused by the spaces between the fan blades.

Two fans of different sizes were used to produce a range of wind speeds above the tube outlet. The smaller fan had a blade length of 152 mm and had two speed settings. The larger fan had a blade length of 305 mm and had three speed settings. The wind speeds produced by these fans are discussed below in section 4.2.2.

A hole 10 mm in diameter was drilled at mid-length of the tube to allow entry of the hot-wire anemometer velocity probe. The anemometer used was the Kane-May KM4007, the specifications of which are given in Appendix A.

Two accessories were constructed to be tested on the apparatus: a venturi fitting and a slotted fitting. Figure 4.1 displays a descriptive layout of the venturi fitting constructed for the laboratory tests. The bowls used were store-bought stainless steel mixing bowls with a diameter of 340 mm at the upper edge and a depth of 150 mm. A circular hole was cut in the bottom of one of the bowls to match the inner diameter of the acrylic tube (139 mm). This bowl was then set upside down on top of the tube. The upper bowl was supported upright above the lower bowl on three threaded support rods 300 mm long placed through holes in the bowl rims spaced at 120° intervals. Screws on either side of the rim of both the upper and lower bowl allowed for the adjustment of the spacing between the bowls, so that the fitting could be tested over a range of bowl spacings. The support rods could also be removed completely to allow for testing of the fitting with only the lower bowl in place.

Figure 4.2 shows the layout of the slotted fitting constructed for the laboratory tests. It was made of a piece of 2 mm thick tinplate 438 mm wide and 450 mm long. Twenty-four slots were cut parallel to the 450 mm side. The slots were cut 300 mm long starting 75 mm from the lower edge of the tinplate. Each slot was 9.1 mm wide, with 9.1 mm spaces between the slots. The ends of each slot were rounded to a semicircle of 9.1 mm diameter. The tinplate was then rolled to form a cylinder 139 mm in diameter and 450 mm long. Below the slots there was 75 mm of unslotted cylinder which fit into the top of the acrylic tube. A top for the fitting was made of Z mm thick acrylic cut to a circle of 142 mm diameter, into which a groove was cut so that it could be fitted over the tinplate at the top of the fitting. The fitting was tested both with and without the top. This configuration of the slotted fitting was

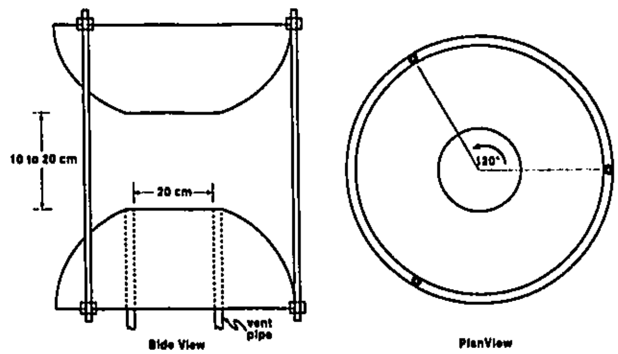


Figure 4.1 Venturi Fitting

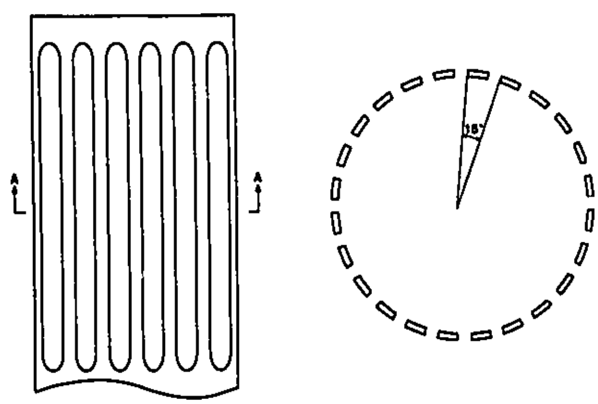


Figure 4.2 Slotted Fitting

taken from similar devices that have been used in the field (Pescod & Price 1978).

The pipe diameters used in the tests were 152 mm in the laboratory and 200 mm in the field. The standard pipe used for VIP latrine ventpipes in Burkina Faso is 200 mm diameter PVC piping. Screens were not used in the laboratory tests but were in place for the tests on the field units.

Initially, it was planned to test a divergent fitting in the laboratory. However after considering the theoretical concepts discussed in Chapter 3, it became clear that the divergent fitting held little promise of improving the ventilation rate. In fact, the divergent fitting is more likely to act as a diffuser and decrease the momentum of the exiting air and thus possibly reduce the ventilation rate. Also, previous experimental work in the field (Ryan & Mara 1983) has shown that the divergent fitting produced no significant difference in ventilation rate over the straight pipe. These two considerations led to the conclusion that little would be gained through the testing of the divergent fitting. However, because of use of these diffusers in the field by other users in Western Africa, it was decided to include some of them in the experimental testing programme.

4.1.2 Experimental Procedure

The wind velocity profile induced by the fans at varying speed settings and distances from the pipe opening was produced by measuring the air velocity above the pipe outlet with the hot-wire anemometer probe. The air velocity was measured at the pipe outlet and at five other locations at 50 mm spacings above the outlet. From this a representative wind velocity for each fan setting can be determined by averaging the velocity readings measured at the six locations. This procedure was repeated for each of the five fan settings used in the laboratory tests.

The air velocity profile within the pipe without accessories (open pipe) was also determined by measuring the velocity at close intervals across the pipe diameter. The velocity was measured as close to the pipe wall as possible (3 mm distance) and then at distances from the wall of 5 mm, 10 mm, 20 mm etc. until the pipe centreline was reached. These tests were conducted using the small fan on the lower setting which corresponds to a wind speed of 0.15 m/s above the pipe outlet. This was done to determine if the profile was sufficiently flat so that a single centreline velocity reading could be used for further tests.

A series of smoke tests was then conducted with the apparatus using the open pipe, venturi fitting and slotted fitting with its cap in place. During these tests a smoke bomb was released just below the inlet at the bottom of the pipe under various wind conditions. The smoke bombs used were Superior #2B one minute smoke candles. The smoke could be seen rising through the transparent pipe so that it was possible to accurately time the delay between smoke entering the bottom and leaving the top of the pipe. Two trials of each test were made.

In this way a qualitative estimate of the velocities in the pipe under the various conditions could be made.

A series of more quantitative tests was then completed with actual velocity measurements being made. The results of the velocity profile measurements indicated that the profile was very flat, with the boundary layer zone being very thin. This meant that the velocity tests could be completed with only a single velocity measurement taken at the pipe centreline, which could be assumed to be representative of the velocity across the entire pipe cross-section.

Tests were completed using the venturi fitting with five different bowl separations (25 mm, 50 mm, 75 mm, 100 mm, and without upper bowl), the slotted fitting both with and with out the top, and with the pipe with no additions. Each configuration was tested under the five wind speeds corresponding to the fan settings (0.15 m/s, 0.42 m/s, 1.36 m/s, 1.70 m/s and 1.98 m/s).

The results of these laboratory tests were sufficiently promising that it was decided to continue with more extensive tests on actual latrines in the field.

Figure 4.3
Internal Velocity

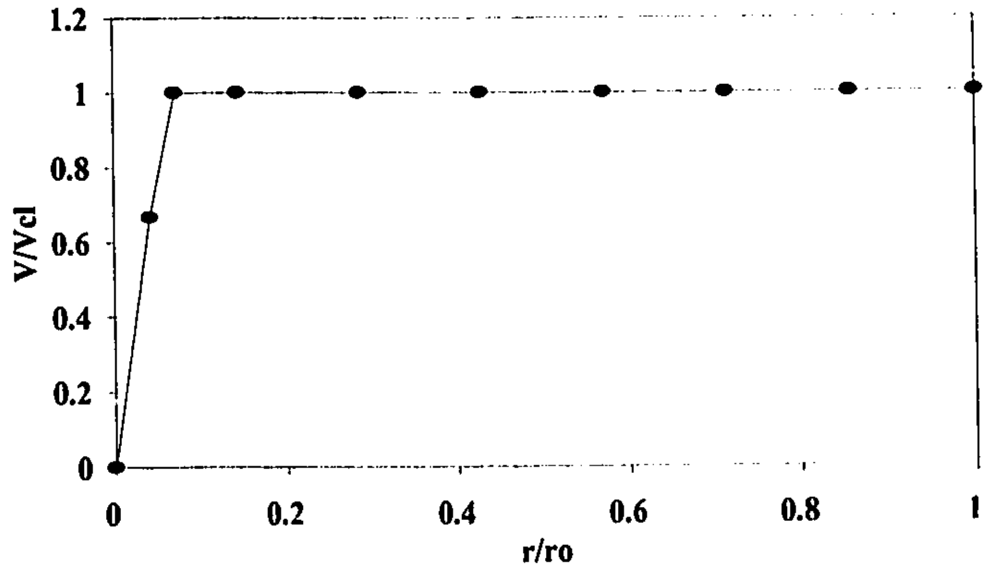
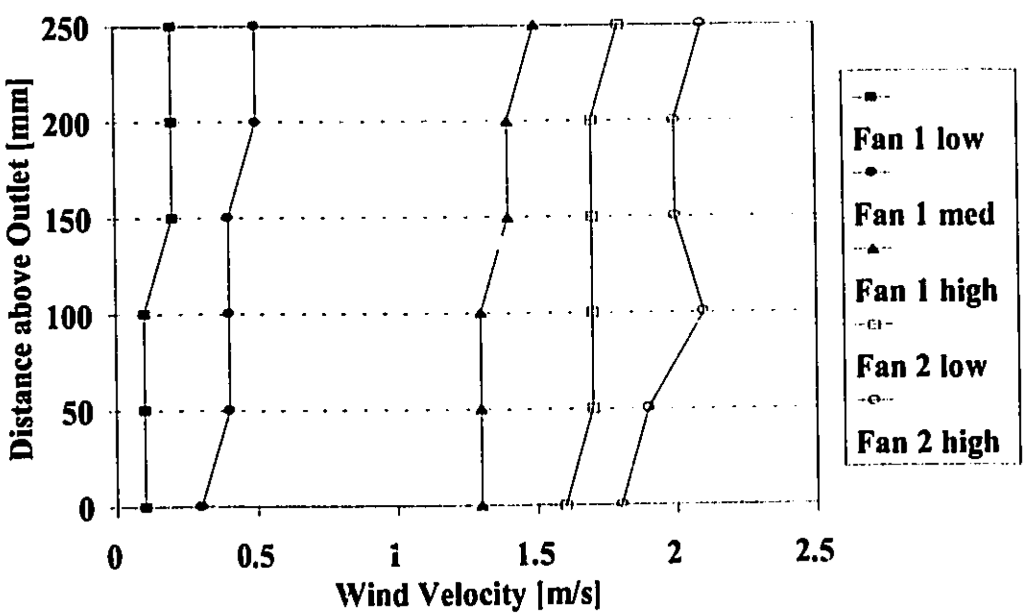


Figure 4.4
Laboratory Wind Velocity



4.2 Laboratory Results

The preliminary trials with the laboratory apparatus were intended to determine the velocity profiles within the vent pipe and above the vent pipe opening. These velocity profiles were important with respect to properly identifying the conditions under which the additions were being tested.

4.2.1 Ventpipe Internal Velocity Profile

The shape of the internal velocity profile within the ventpipe is important in determining how representative the centreline velocity is of the average velocity in the pipe. Turbulent velocity profiles, due to efficient momentum transfer mechanisms, are flat in profile, with the average and centreline velocities differing by only a small amount. Laminar flows display a more pronounced parabolic velocity profile with the peak centreline velocity significantly higher than the average velocity.

The internal velocity profile for the open pipe was measured under the lowest fan speed (0.15 m/s wind speed) and is shown in Figure 4.3 in non-dimensional form. In Figure 4.3, the x-axis label (r/r_0) is the distance from the wall (r) rendered non-dimensional by dividing by the pipe radius (r_0). Thus a r/r_0 value of 1.0 represents the centreline. The velocities measured were non-dimensionalized by dividing by the centreline velocity (V_{cl}). From Figure 4.3 the profile can be see to be flat at the centreline velocity, except for a thin boundary layer close to the pipe wall. Using area weighted averaging, the average velocity was found to be 6.5 per cent lower than the centreline velocity. The Reynolds number (Re) of this flow is 2593, a value indicating that the flow is very likely to be out of the pure laminar zone. Although the flow may still be in the transition zone, the flat velocity profile is evidence that the flow is sufficiently turbulent for the centreline velocity to well represent the average velocity. Since these calculations were made with the lowest fan speed and thus the lowest pipe velocity, all other flows will have higher Re (at the highest velocity used in the tests Re was 5085) and thus have greater turbulence. It was therefore concluded that for all the flows under consideration, the centreline velocity could be considered as representative of the average flow in the pipe. For all further trials it was necessary to measure only the centreline velocity.

4.2.2 Velocity Profile Above Pipe

The velocity generated above the ventpipe by the two fans at various settings was measured at six heights above the pipe opening. As can be seen from Figure 4.4, the fans produce a reasonably constant air velocity above the pipe. This was to be expected since the apparatus was mounted sufficiently high above the laboratory floor to limit the frictional effects so that no boundary layer effects from the floor are seen.

From these tests it was possible to convert the fan speed into an air velocity to be used for the hot-wire anemometer velocity tests. These velocities are presented in Table 4.1. For the following presentation, the air velocities rather than the fan speeds will be quoted.

Table 4.1 Fan Wind Speeds for Velocity Tests

Fan Speed	m/s (avg)
1 low	0.15
1 med	0.42
1 high	1.36
2 low	1.70
2 high	1.98

4.2.3 Smoke Tests

The smoke tests were performed as a preliminary investigation to investigate the effects of the fittings. The results are presented in Appendix C and displayed graphically in Figure 4.5, which is a plot of the average of the induced vent pipe velocities for the two trials. This velocity was calculated from the time taken by the smoke to ascend the acrylic pipe. From this graph it can be seen that, apart from still conditions, the venturi fitting appears to increase the rate of smoke ventilation under all wind conditions. The slotted fitting performs only as well as the open pipe for low wind and slightly better for higher wind conditions.

Under still conditions, the smoke is rising solely due to convection, as it is slightly hotter than ambient temperature. Thus, under still conditions, the fittings are contributing no amplification of the effect of the wind, but are adding to the losses in the system. It is, therefore, not surprising that neither fitting performed as well as the open pipe under still conditions.

From these results it would appear that the fittings might have a threshold wind value below which the added friction losses due to the fitting outweigh any increases in flow that might have been seen. Above the threshold value, the increased ventilation due to the fitting overcomes the frictional losses. The venturi appeared to have a low threshold wind value, while the threshold of the slotted fitting was somewhat higher. The further, more quantitative velocity tests, were designed to determine the threshold values more accurately and to give a clearer idea of the ventilation increases to be expected in the field using the additions.

4.2.4 Velocity Tests

Using the same apparatus as the smoke tests, the fittings were tested more rigorously using the hot-wire anemometer velocity probe. The fittings were tested under various configurations and under the five different wind conditions discussed in section 4.2.2 (0.15 m/s, 0.42 m/s, 1.36 m/s, 1.70 m/s and 1.98 m/s). The venturi fitting was tested with four bowl separation distances (25 mm, 50 mm, 75 mm, 100 mm) and without the upper bowl. The slotted fitting

Figure 4.5

Laboratory Smoke Test Results

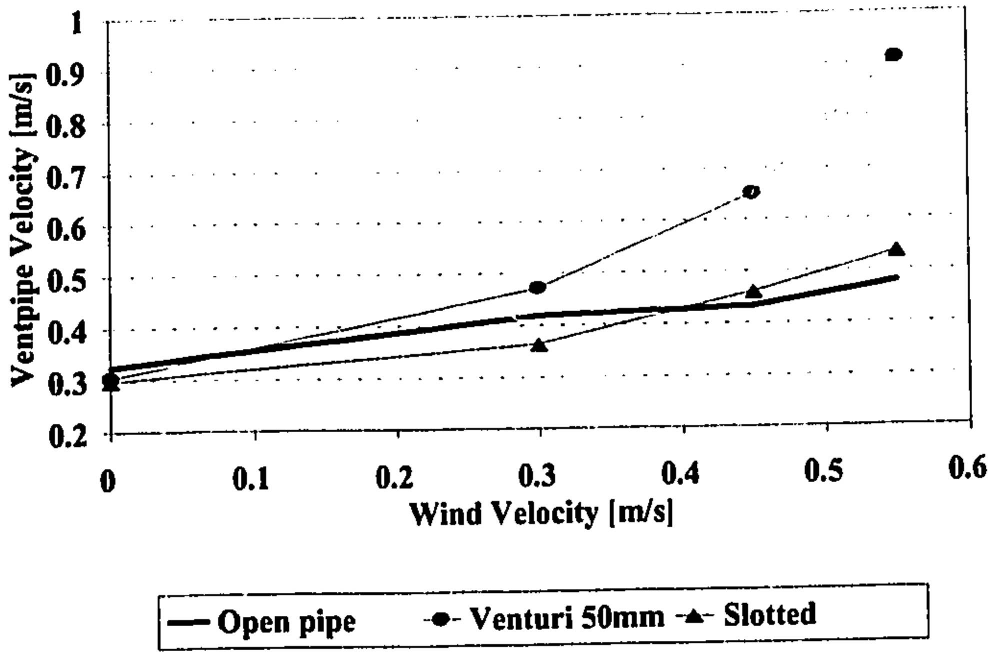


Figure 4.6

Laboratory Results for Venturi Fitting

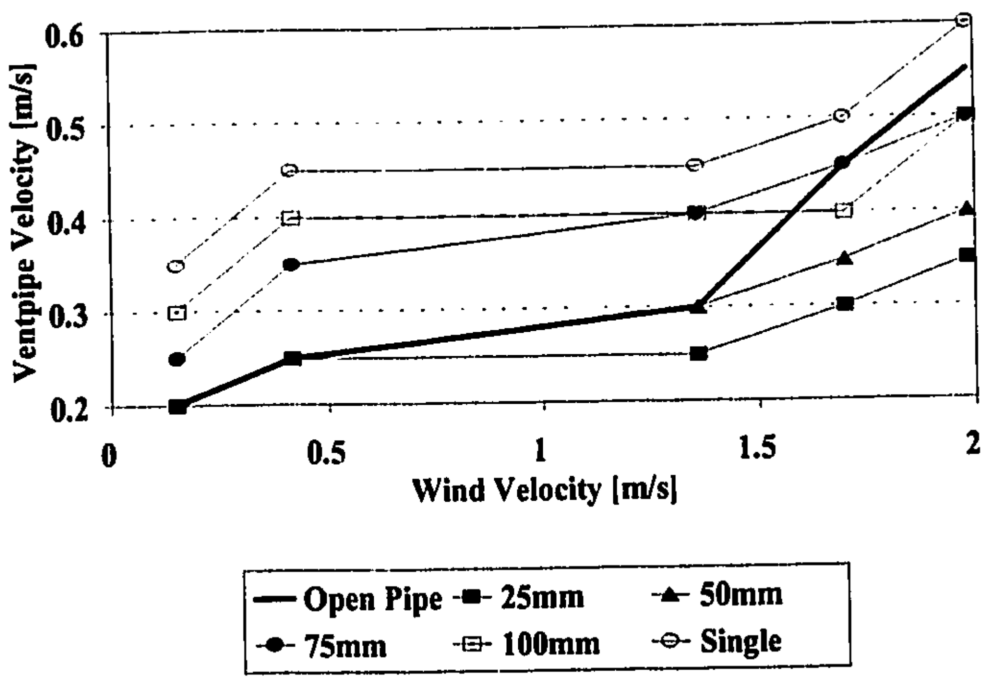


Figure 4.7

Laboratory Results for Slotted Fitting

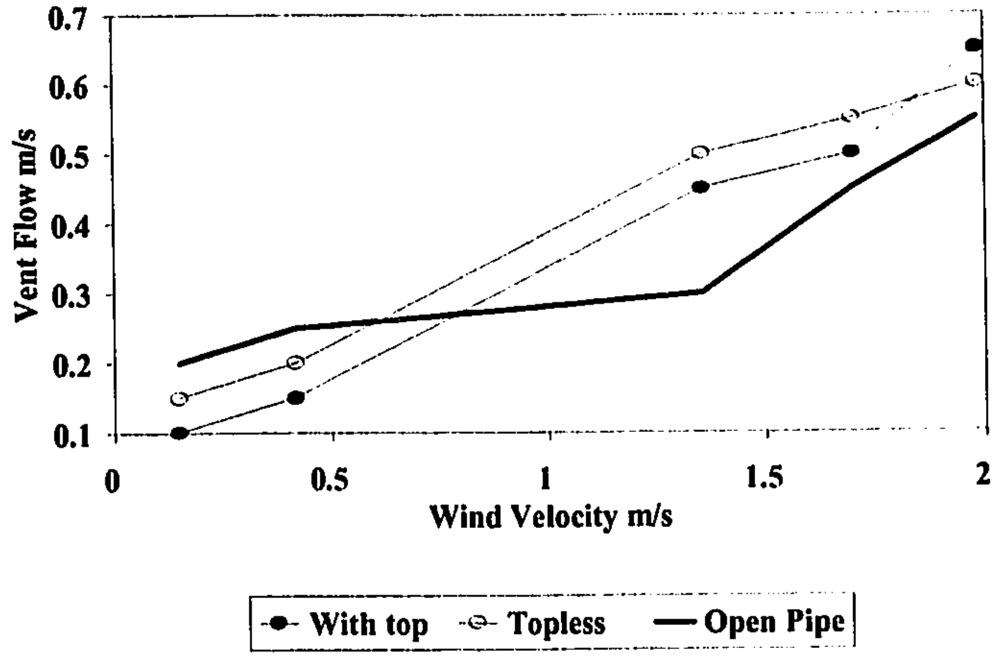
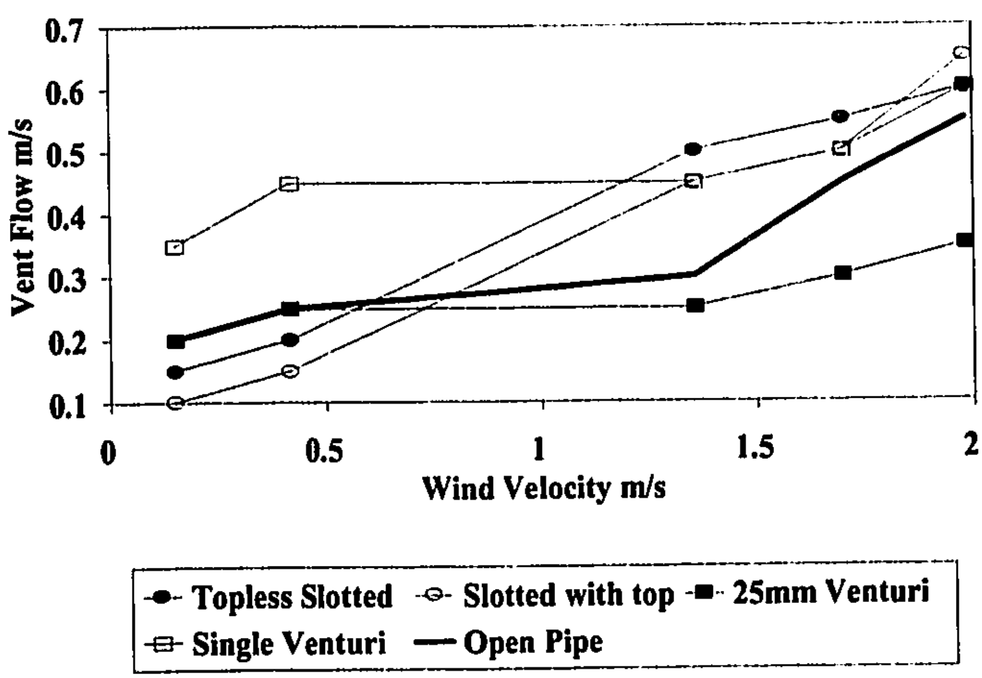


Figure 4.8

Combined Laboratory Results



was tested both with and without the removable top. For each configuration the velocity at the pipe centreline was measured twice for each of the five wind velocities. The results are presented in Appendix C and plotted in Figures 4.6, 4.7

Figure 4.6 displays the ventpipe flow rate for the venturi fittings tested in the laboratory. From this it can be seen that the single venturi produces the greatest increase in the flow rate over the open pipe for all wind speeds. The double venturi fittings produce smaller increases than the single venturi, with this effect becoming more marked as the separation distance decreases. This is likely due to the increased skin friction on the bowl surfaces as the opening between the upper and lower bowl is narrowed. This effect is most marked with the venturi fittings with 25 mm and 50 mm bowl spacings which are only equivalent in performance to the open pipe at low wind speeds and are significantly worse at higher wind speeds.

The slotted fitting performance is shown in Figure 4.7. It can be seen here that the slotted fitting performs better than the open pipe only for wind speeds greater than 0.8 metres per second. For wind values below this value, the venting flow is reduced as compared to that of the open pipe. From this it can be seen that the slotted fitting has a threshold wind speed, in this case 0.8 metres per second, which must be exceeded for the fitting to be effective. It is also evident that the slotted fitting generally performed slightly better without the top.

For comparison, the results for both the slotted and venturi fittings are displayed together in

Figure 4.8, which displays the range of performance of the venturi fitting by displaying the extremes of performance, the single venturi and the double venturi with 25 mm separation. From this it can be seen that the single venturi fitting produces superior performance to the slotted fitting for lower wind speeds. As the wind speed increases, the performance of the slotted fittings increase to reach that of the single venturi at approximately 1.2 metres per second after which the performance of all three fittings is approximately the same. These results would indicate that the single venturi is the superior fitting in that it produces ventilation rate increases over the entire range of winds tested, while the slotted fitting is not effective at low wind speeds.

The laboratory results discussed in this section indicated that it was likely that both the venturi and slotted fittings could produce an increase in the ventilation rate. It appeared that under laboratory conditions the single venturi fitting was the most successful. This result remained to be verified under field conditions.

Chapter Five

Field Investigation

5.1 Field Test Methodology

The field test portion of the study was undertaken with the cooperation and assistance of CREPA in Ouagadougou, Burkina Faso between November 1993 and August 1994. The experience and local knowledge of the engineers working at CREPA was invaluable throughout the planning and execution of the testing program.

5.1.1 Site Selection

It was decided that the tests would be carried out on existing latrines which had been built in the Ouagadougou area with the assistance of CREPA. Over the past five years CREPA has given technical and financial aid to assist the construction of VIP latrines at approximately sixty locations in and around the city. A list of these sites was drawn up and each was examined for suitability for the testing program.

Not all the latrines examined were suitable to be used for the tests. To aid in the choice of sites, a list of criteria, both technical and non-technical, was used to select the suitable latrine sites. It was felt that the site should conform to the following criteria;

·the latrine should be in good repair
·the ventpipe easily should be accessible for testing
·ventpipe preferably made of PVC plastic
·latrine pit should be less than ¾ full to avoid ventpipe location change during the test
·plans of the latrines should be available
·the family or institution must be willing to allow access for the tests

The fourth criteria was included since most of the latrines considered were alternating double pit VIP latrines. In this design, when one of the pits is filled, it is closed and the other pit is brought into service by moving the ventpipe to the other side of the latrine superstructure. Therefore, by ensuring that the same pit will be in service for the duration of the study, the major change in conditions represented by the ventpipe relocation is avoided.

With these criteria in mind, six sites were chosen. Four of the sites were private family compounds with alternating double pit VIP latrines built to the standard plan developed by CREPA. These sites were identified by the name of the *quartier* of the city in which they were found: Cité de l'avenir, Dassango, Cité AN II and Pissi. The other two sites were schools: Ecole de Tanghin-Taambila and Ecole de Dagnoin, with two blocks each of multiple-pit communal latrines. The design plans of the latrines used are displayed in Appendix B.

The vent pipe additions were then constructed to fit the ventpipes in place on the latrines chosen. The ventpipes used were 200 mm external diameter PVC pipes, with 5 mm wall thickness. Three basic ventpipe addition designs were constructed for use in the field tests.

The venturi fitting was constructed of plastic bowls easily obtained in the central market of Ouagadougou. The bowls were 100 mm deep with a diameter of 300 mm at the upper rim. The lower portion of the venturi was formed by cutting a circle of 190 mm diameter in the bottom of one of the bowls and fixing it to the top of the ventpipe with four screws. The flyscreen was placed under the lower bowl so that it would be held in place across the ventpipe outlet. Supports for the upper bowl were made of 10 mm diameter circular iron bar. These consisted of horizontal rings which fit around the bowls at the rims, held apart by three vertical support rods welded to the rings at 120° spacing. Accessories were constructed with bowl spacings of 100 mm, 150 mm, 200 mm, and without the upper bowl.

The slotted fittings were constructed of 450 mm lengths of 200 mm outer diameter PVC tubing with 5 mm wall thickness. Twenty-four slots were cut so that the slots and the tabs between the slots were of equal width (13 mm). The slots were 300 mm long and started 75 mm from the top of the fitting, leaving 75 mm of unslotted pipe below the slots. The slots were not rounded at the end but were filed smooth after the slots were cut. The bottoms of the fittings were softened with a torch, after which they could be stretched over the ventpipe outlets on the chosen VIP latrines. The flyscreen was fitted under the accessory as it was put in place. Tops for the fittings were made of tinplate cut to a 200 mm circle with tabs bent to hold them in place. Four of the slotted fittings were tested with the tops and four were tested without the tops.

The divergent fittings were made of 2 mm thick tinplate. The fitting consisted of two parts: a sleeve of 190 mm diameter and 100 mm long was soldered to a diverging section which started at a 190 mm diameter and expanded to 250 mm or 350 mm diameter over a length of 400 mm. Three fittings of 250 mm upper diameter and two of 350 mm upper diameter were constructed. Flyscreens were placed under the accessory to be held in place between the sleeve and the ventpipe inner wall.

The following ventpipe additions were constructed.

Ecole Tanghin-Taambila Bloc A
- slotted fitting without top
- slotted fitting with top
- divergent fitting with 25 cm top diameter
- divergent fitting with 35 cm top diameter
- control (no fitting)

Ecole Tanghin-Taambila Bloc B
- venturi fitting with 20 cm separation
- venturi fitting with 15 cm separation
- venturi fitting with 10 cm separation
- venturi fitting without upper bowl
- control (no fitting)

Ecole Dagnoin Bloc A
- venturi fitting with 10 cm separation
- venturi fitting without upper bowl
- slotted fitting without top
- slotted fitting with top
- control (no fitting)

Ecole Dagnoin Bloc B
- divergent fitting with 25 cm top diameter
- divergent fitting with 35 cm top diameter
- slotted fitting without top
- slotted fitting with top
- control (no fitting)

Cité de l'avenir
- slotted fitting without top

Quartier Dassango
- slotted fitting with top

Cité AN II
- venturi fitting with 15 cm separation

Quartier Pissi
- divergent fitting with 25 cm top diameter

Originally during the laboratory portion of the project, the divergent fitting was not considered for testing. This decision was made because testing by the UNDP Technical Advisory Group (Ryan & Mara 1983) had shown that the divergent fitting was not effective in increasing the ventilation rate in VIP latrines. However, it became apparent that references (Lochery & Adu-Asah 1985, Winblad & Kilama 1988) published since the UNDP work were still recommending the use of diverging outlets on VIP latrine ventpipes. Also, the author, on trips to Togo and Bénin, saw many examples of recently built VIP latrines with diverging ventpipes. It became obvious that the diverging pipe was still considered useful by a number of VIP latrine builders. For this reason, it was decided that it was important to verify the results of the UNDP tests and thus divergent fittings were included in the field tests.

Ideally, a greater number and variety of accessories would have been tested at each location, allowing for a greater range of comparison. However, several practical considerations of the conditions in Ouagadougou made this impossible. The CFA, the currency used in Burkina Faso, was devalued by 50 per cent at the beginning of the testing programme. The resulting upheaval in the economy made usually easily available materials such as PVC piping and tinplate difficult to purchase. Also, transportation within the city of Ouagadougou and the outlying area was such that the more frequent visits to the sites necessitated by a greater number of test accessories would have been very difficult given the conditions in Ouagadougou.

Given these limitations, the fittings to be tested at each site were chosen so that a comparison could be made between all the accessories. All types of accessories were tested at each of the two schools, giving as broad a range of comparison as possible. These tests were than supported by tests of individual fittings at private residences.

All accessories were designed so that they could be easily constructed by craftsmen with materials available locally. The venturi accessories were constructed of plastic bowls available widely in the Ouagadougou markets. The steel bars, sheet metal and PVC piping needed for the divergent and slotted accessories, are required for other parts of the latrine structure and are available from local building supply vendors. Thus, the addition of these accessories should not pose material problems during the construction of the latrines.

5.1.2 Latrine Testing

The latrines were then prepared for the testing by flushing out cobwebs or other blockages from the ventpipes with two buckets of water. A hole 1 cm in diameter was drilled at the midpoint of each ventpipe to allow access of the anemometer velocity probe. This hole was covered between tests to prevent access of flies and other insects to the latrine pit.

For each block of the communal latrines, a control pipe was chosen which was to remain without an attachment throughout the testing. A series of velocity readings were taken on each pipe under several wind conditions. These readings were then compared to the control pipe to confirm that all the pipes displayed the same vent velocity to wind velocity characteristics.

The latrine sites were then visited twice a week for six months. At each visit the venting velocity through each ventpipe was measured simultaneously with the wind velocity at the height of the pipe opening. The ventpipe velocity was measured with a hot wire anemometer while the wind velocity was measured with a cup anemometer. Other data gathered included: ambient air temperature, air temperature in the latrine superstructure, air temperature in the ventpipe, wind direction and weather conditions.

Three of the family latrines (Cité de l'avenir, Cité AN II and Quartier Dassango) were fitted with permanent accessories which stayed in place for three months of data collection. The accessories were then removed and a further three months of data was collected with the open pipe. The fourth family latrine was fitted with a removable accessory so that a reading for both the open pipe and the accessory could be taken at each visit.

5.2 Field Results

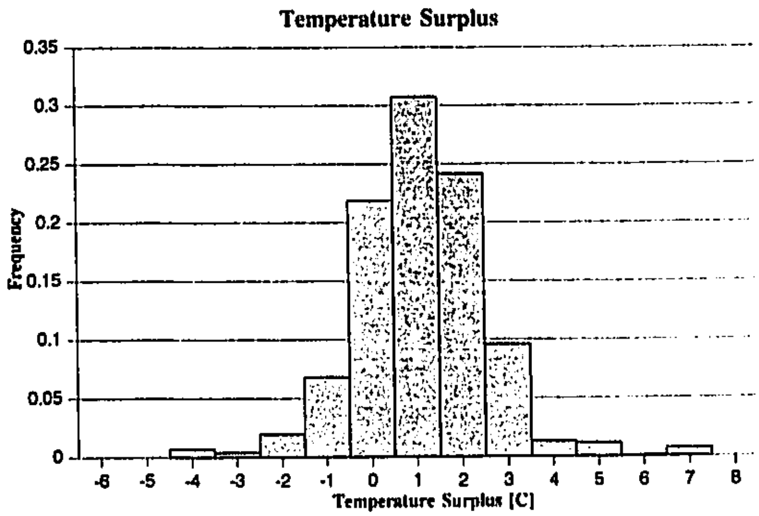
Data was gathered for each latrine site in Ouagadougou over a six-month period. In order for the effectiveness of the ventpipe additions to be properly evaluated, it was necessary to be able to compare the ventilation rates for the latrines both with and without the additions. For the single family dwellings, this was achieved by taking ventpipe velocity measurements on the single ventpipe with and without the ventpipe addition. In each block of the multiple-pit school latrines one ventpipe was left without an addition, so that for each reading taken, a baseline comparison was available. The full data set for the field tests is presented in Appendix D.

Because the latrine superstructure is not symmetrical, the ventilation rate will depend to a certain extent on the wind direction. The front of the latrine with the entrance doorway offers a greater surface area for air entry than either the sides or the back, thus creating a greater positive pressure within the superstructure to drive pit ventilation. Previous workers (Morgan & Mara 1982, Ryan & Mara 1983) have suggested that superstructure orientation with respect to prevailing wind direction should be the dominant factor when deciding on the placement of a new VIP latrine. For this reason ventilation rates can only be compared reasonably when taken under similar wind directions. For the analysis of the field data, comparisons were therefore only made between ventilation rates produced under the same wind direction. For the two school locations, the prevailing wind was such that it approached the latrine blocks from the side. Therefore the bulk of the data gathered for the schools was under the side wind condition. Although data was gathered for winds toward the front and back of the latrines, it is questionable whether there is sufficient data under these conditions to draw firm conclusions.

At each school site, all three fitting types (venturi, slotted and diverging) were tested so that a comparison under similar conditions could be made. The results for each fitting type will be presented separately in the following sections.

Previous work by the UNDP Technical Advisory Group (Ryan & Mara 1982) indicated that effect of solar heating of the vent pipe is insignificant when compared with the effect of wind suction above the pipe. This is in line with calculations and laboratory tests obtained in this thesis (see pp 37-41). Nevertheless, it was a concern that the convective velocity induced by the heating of air within the pipe might affect the velocity readings. To see if this effect is

Figure 5.1



important, the air temperature within the pipe was measured for each velocity reading. The temperature surplus, the difference between vent pipe air temperature and the ambient air temperature, was then calculated. A histogram of the temperature surplus is presented in Figure 5.1. As can be seen from this chart the temperature difference is clustered close to zero. The mean temperature surplus is 0.65 °C and the standard deviation is 1.45 °C. The distribution is very close to normal in shape, thus almost all readings fall within a temperature surplus of less than three standard deviations of the mean (-3.7 °C to 5 °C), with 84 percent occurring at temperature surpluses of less than one standard deviation of the mean (-0.8 °C to 2.1 °C).

The results of the analysis outlined in Chapter 3 indicate that for a temperature surplus distribution such as that displayed in Figure 5.1, the thermally induced component of velocity can be expected to be of the order of 0.35 m/s for an extreme value of temperature surplus. This is on the lower boundary of the values of velocity actually measured in the field. From this it can be concluded that the thermally induced component of velocity is, in most cases, significantly smaller than the wind induced component.

Another consideration was the effect of one fitting on the fittings downwind for a block of communal latrines. This wake effect would only be a factor when the wind approaches the latrine structure from the side. The fittings can be expected to create a wake which would produce an oscillating effect on the wind velocity downstream of the fitting. However the atmosphere near the earth's surface is naturally very turbulent with eddies and swirls continuously producing wind gusts. Investigations into the effect on downstream cylinders of the wake produced by a cylinder (Ohya et al 1989) show that no noticeable effect is felt by the second cylinder when the cylinders are placed at a difference greater than seven diameters. Further, as the wind direction varies by only a small angle (10°) from the line between the two cylinders, the effect of the upstream cylinder falls dramatically. Considering that the vent pipes are placed at a separation of greater than ten diameters, the wake effect experienced by a downwind pipe can be expected to be small compared with the already naturally occurring gustiness.

5.2.1 Divergent Fitting

The divergent fitting was tested on five latrines: two at each school and one at a private residence in Quartier Pissi. Two rates of divergence were tested: a fitting that flared from the pipe diameter out to 250 mm and one that flared to 350 mm over the 400 mm length. The ventpipe velocity versus wind speed data for a side wind are presented graphically in Figures 5.2 to 5.5.

From these figures it is clear that the neither the wide nor narrow diverging fitting produced ventilation rates significantly different from the rates observed without the fittings in place. Results for winds toward both the back and front of the latrine also show no difference between the fitting and the open pipe (i.e. the control). However, since the wind was predominantly from the side of the latrine, the data for front and back winds is somewhat more limited than that for the side wind.

A divergent fitting with an upper diameter of 250 mm was also tested on a private house in quartier Pissi. The results from this test are very similar to those conducted at the schools. Under side wind conditions an increase in the ventilation rate of 2 per cent over the open pipe was observed. Under front wind conditions this increase was 5 per cent. These increases are not large enough to justify the conclusion that the divergent fitting had any significant effect on the ventilation rate.

Figure 5.2
Divergent 25 cm : Ecole Tanghin Bloc A

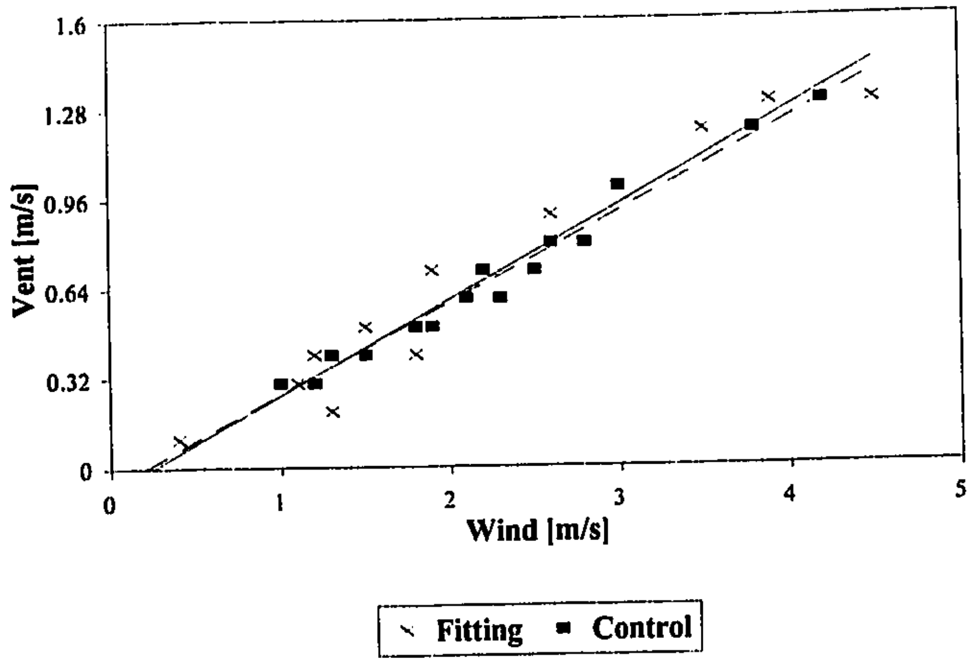


Figure 5.3
Divergent 35 cm : Ecole Tanghin Bloc A

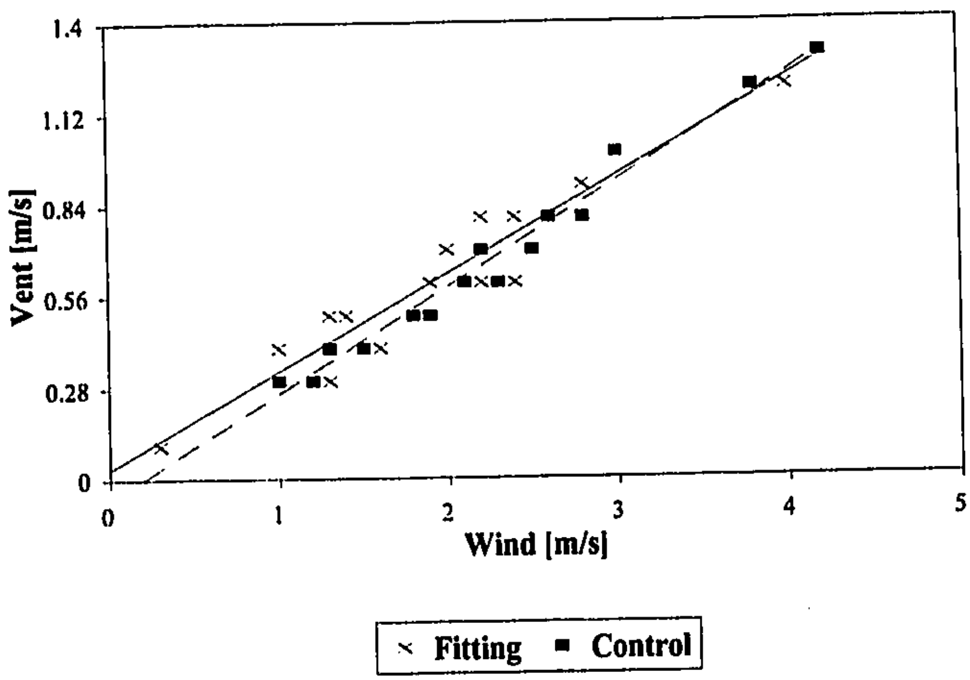


Figure 5.4
Divergent 25 cm : Ecole Dagnoin Bloc B

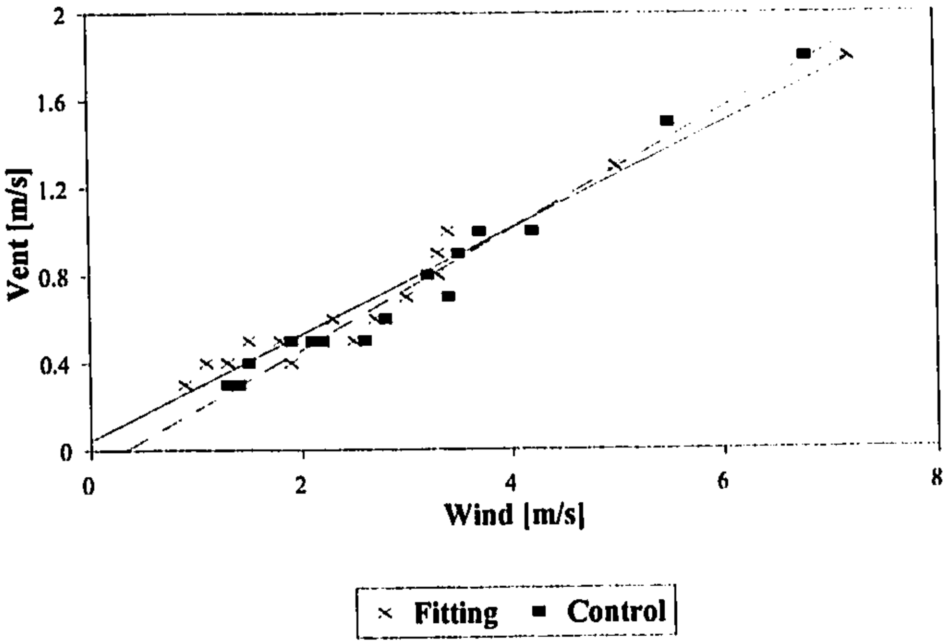
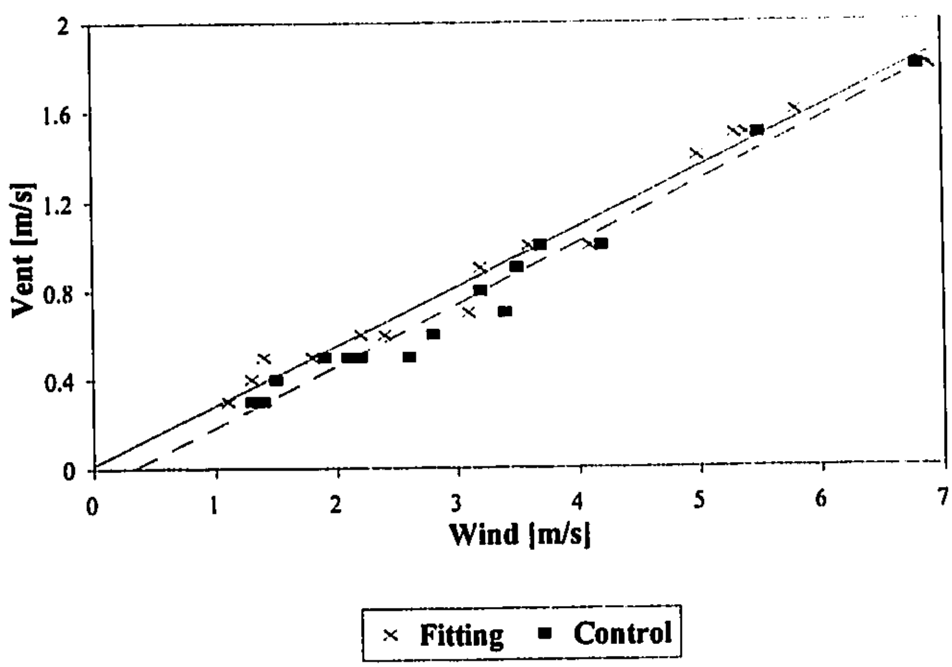


Figure 5.5
Divergent 35 cm : Ecole Dagnoin Bloc B



These results support the findings of the work done in Zimbabwe by the World Bank Technical Advisory Group which investigated VIP ventilation during the early part of the U.N. Water and Sanitation Decade (Ryan & Mara 1983). They had recommended that the use of divergent ventpipes be discontinued since they produced little ventilation improvement for the additional cost.

5.2.2 Slotted Fitting

The slotted fitting was tested on eight latrines: two at Ecole Tanghin, four at Ecole Dagnoin and two at private residences. Four of these were slotted fittings with tops and the remaining four had no tops. The data for these latrines for side wind conditions is presented in Figures 5.6 to 5.11.

Two slotted fittings were also tested at private houses: a topless fitting at Quartier Dassango and a fitting with a top at Cité de l'avenir. The results found in these tests agree well with those found in the school tests, although care must be taken in making comparisons. The private houses represent unique environments in which only one fitting is tested as opposed to the school at which a number of fittings are tested in comparable similar environments.

Both the fitting with a top and the topless fitting display the same general characteristics. For low wind conditions the slotted fittings show no improvement over the open pipe, but for

Figure 5.6
Topless Slotted : Ecole Tanghin Bloc A

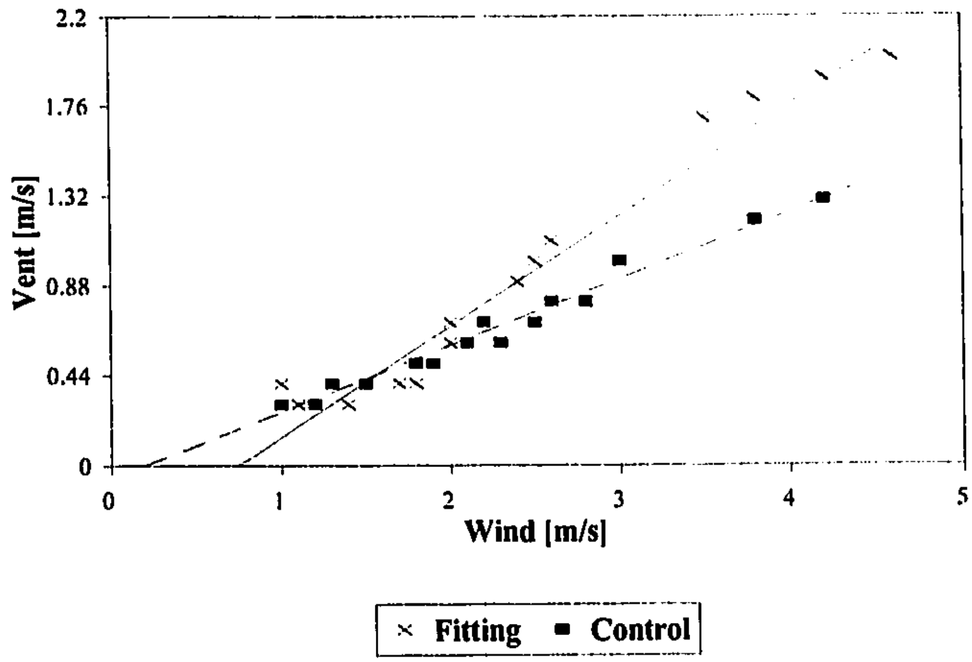


Figure 5.7
Slotted With Top :Ecole Tanghin Bloc A

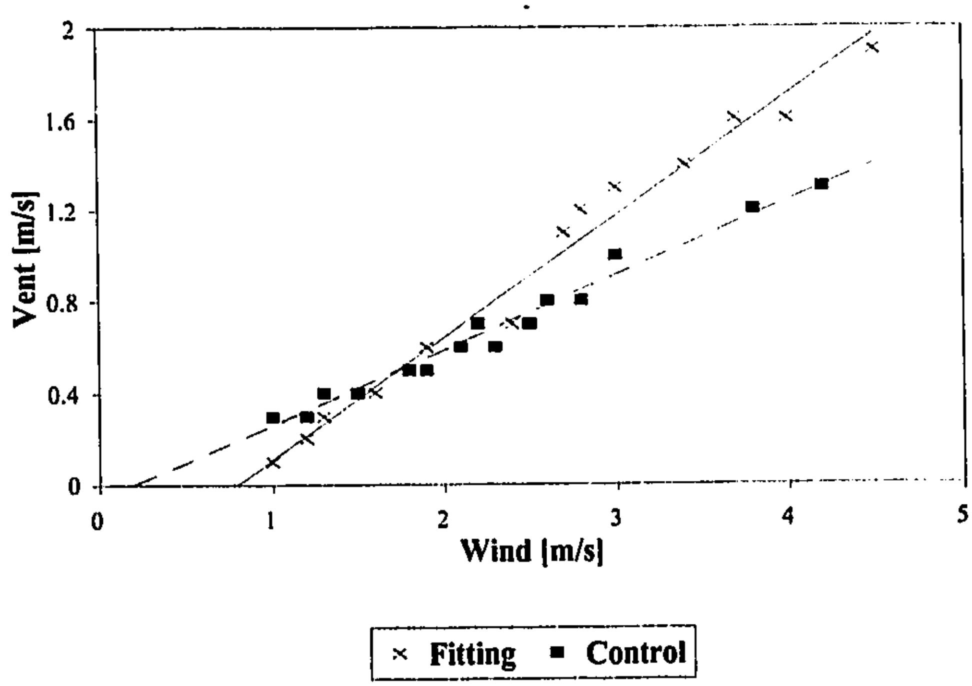


Figure 5.8
Topless Slotted : Ecole Dagnoin Bloc A

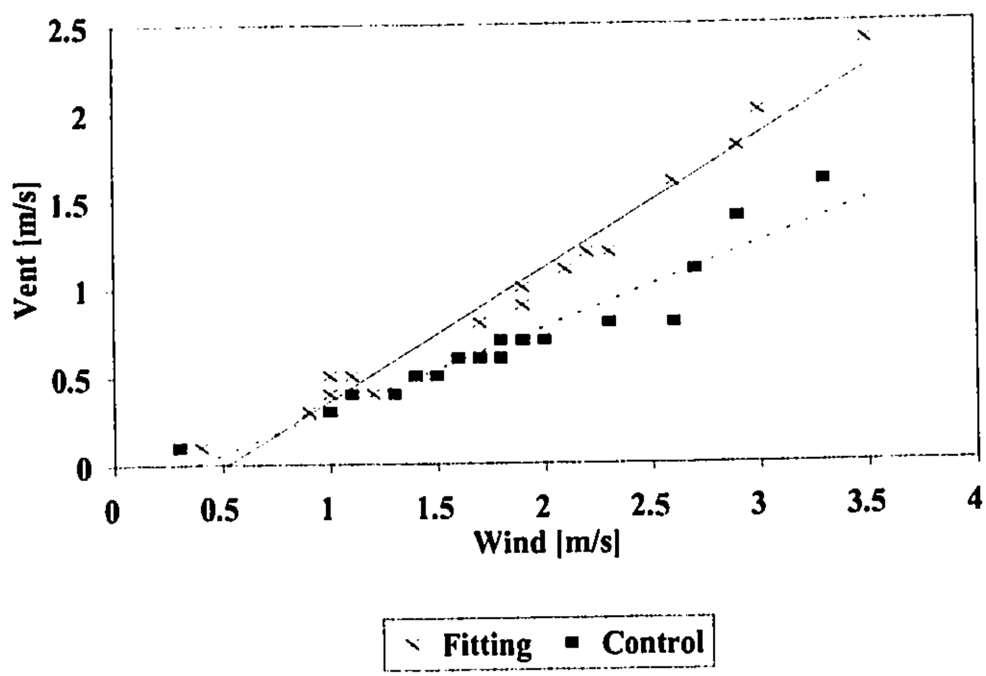


Figure 5.9
Slotted With Top :Ecole Dagnoin Bloc A

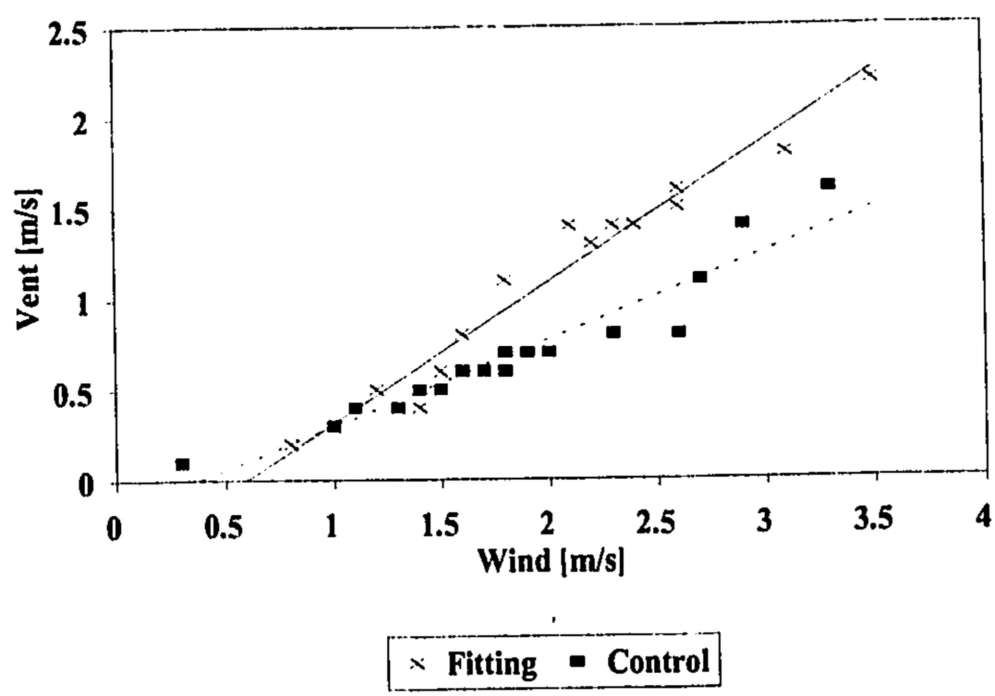


Figure 5.10
Topless Slotted : Ecole Dagnoin Bloc B

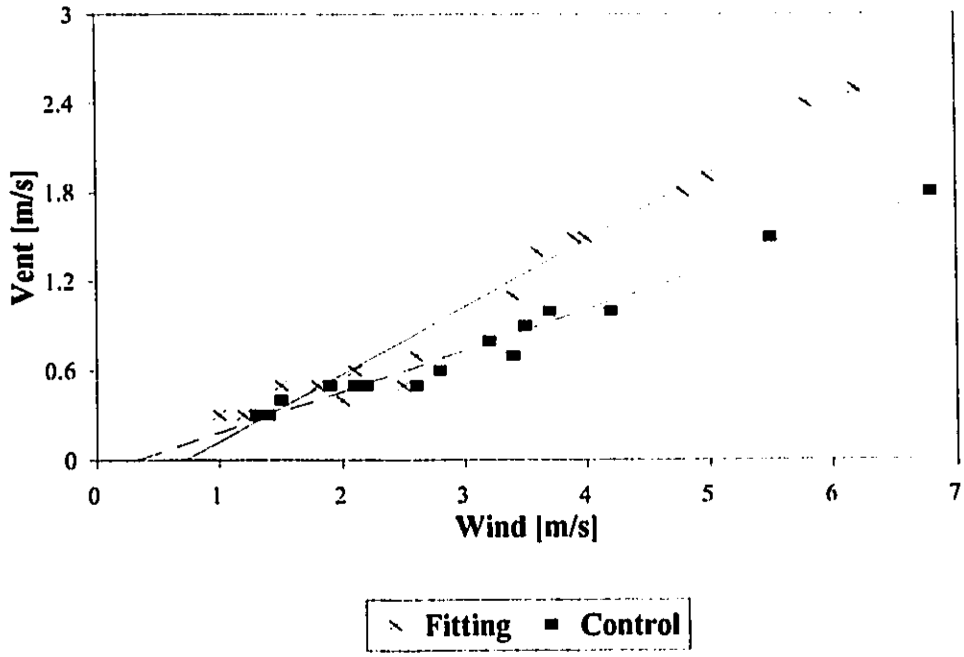
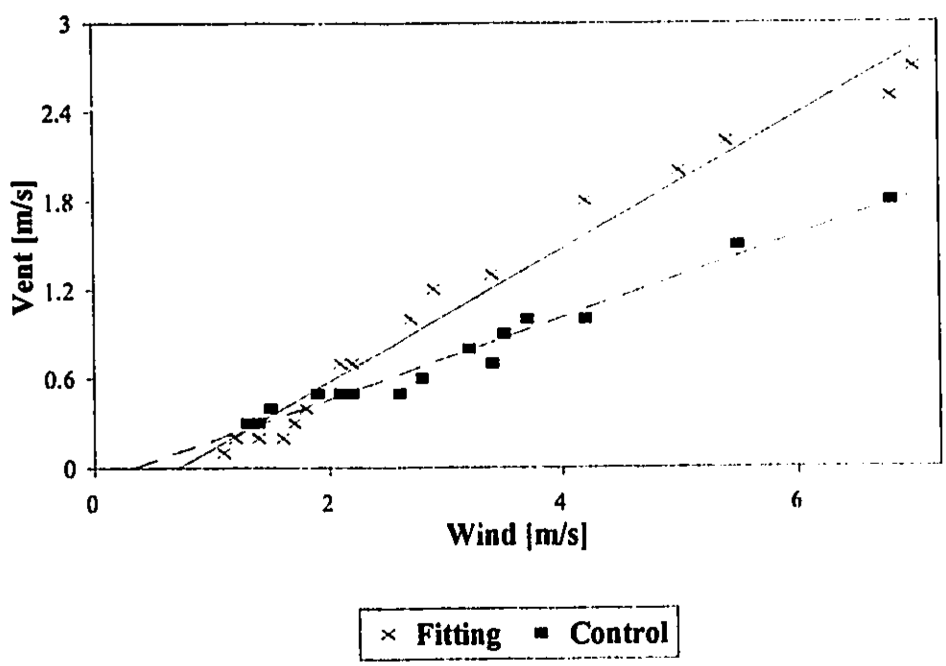


Figure 5.11
Slotted With Top :Ecole Dagnoin Bloc B



higher winds both fittings show a significantly higher venting velocity. Thus, for the slotted fitting there are two important parameters to determine: the minimum wind velocity above which the fitting becomes effective and the degree of improvement the fitting provides for winds above this minimum.

In order to aid in determining the effectiveness of the fittings, the vent speed versus wind speed data were regressed to a linear curve fit. The data fit to a straight line quite well with all coefficients of correlation above 0.96. These lines can then be compared to those of the open pipes for each of the latrine sites to determine the effectiveness of the fitting. The linear fits were displayed in Figures 5.12 to 5.17. The full results of the linear regression analysis is displayed in Appendix E.

Referring to Figures 5.6, 5.8 and 5.10, it can be seen that the topless slotted fittings begin to show an improvement over the open pipe for wind speeds of between 1 m/s and 2 m/s and above. There does not appear to be a significant difference in this cross-over point between slotted fitting with a top and the topless fitting. It appears that neither fitting shows a significant advantage in terms of minimum effective wind speed. Using the linear regression lines fitted to the experimental data for the eight slotted fittings tested, the average point at which the fitting becomes more effective than the open pipe is 1.3 m/s. That is an increase in the rate of ventilation over the open pipe can be expected for the slotted fittings for any wind speed above 1.3 m/s.

The two slotted fittings in Bloc A of Ecole Dagnoin compare favourably with the open pipe of Bloc A. The fitting without a top produces a slightly higher increase in ventilation rate than the fitting with a top, for wind values above the minimum effective value. To provide a comparison, at a wind speed of 3.5 m/s, the maximum to be expected during the windy periods in Burkina Faso, the fitting with a top increased ventilation by an average of 40 per cent over the open pipe. Under the same conditions the fitting without a top produces an increase of 42.5 per cent. From this it can be seen that the presence of the top makes only a slight difference in the performance of the slotted fitting. The comparison of the slotted fittings at Ecoles Dagnoin and Tanghin and the two private houses is shown in Table 5.1.

Table 5.1 Slotted Fitting

Ventilation Increase Over Open Pipe at a Wind Speed of 3.5 m/s

	With Top	Topless
Dagnoin A	51.2 %	50.3 %
Dagnoin B	43.5 %	43.5 %
Tanghin A	33.8 %	38.8 %
Cité de l'avenir	-	37.5 %
Quartier Dassango	31.6 %	-
Average Values	40.0 %	42.5 %

5.2.3 Venturi Fitting

The venturi fitting was tested on seven latrines: two at Ecole Dagnoin, four at Ecole Tanghin and one at a private residence in Cité AN II. The venturi fitting was tested with three different bowl separations as well as without the upper bowl. The data for the school latrines under side wind conditions is presented in Figures 5.12 to 5.17.

From these figures it can be seen that all the venturi fittings, regardless of the bowl separation, produce an increase in the venting rate over the open pipe. Thus for the venturi fitting there appears to be no minimum wind speed necessary for the fitting to be effective.

Similarly to the data for the slotted fittings, the data for the venturi fittings were fit to a line for ease of comparison. A comparison could then be made between the two venturi fittings at Ecole Dagnoin and between the four fittings at Ecole Tanghin.

Again, for comparison, the increase in ventilation rate over the open pipes at a wind speed of 3.5 m/s is shown in Table 5.2. From this table it can be seen that topless venturi fitting and the venturi fitting with a 20 cm separation produce approximately the same increase in ventilation rate. This increase is greater than that produced by fittings with separations of less

Table 5.2 Venturi Fitting

Ventilation Rate Increase Over Open Pipe for a wind speed of 3.5 m/s

Dagnoin A	Venturi 10 cm separation	19.7 %
	Single Venturi	43.1 %
Tanghin B	Venturi 20 cm separation	42.6 %
	Venturi 15 cm separation	33.3 %
	Venturi 10 cm separation	25.1 %
	Single Venturi	45.4 %
Cité de l'avenir	Venturi 15 cm separation	23.7 %

than 20 cm.

The field tests have shown that the slotted and topless venturi accessories were successful in increasing the ventilation rate through actual VIP latrines. However, the divergent fitting appears to be ineffective. It then remained to determine which of the two effective accessories is feasible for widespread use given the prevailing climatic, economic and social conditions in Burkina Faso.

Figure 5.12
Venturi 20 cm : Ecole Tanghin Bloc B

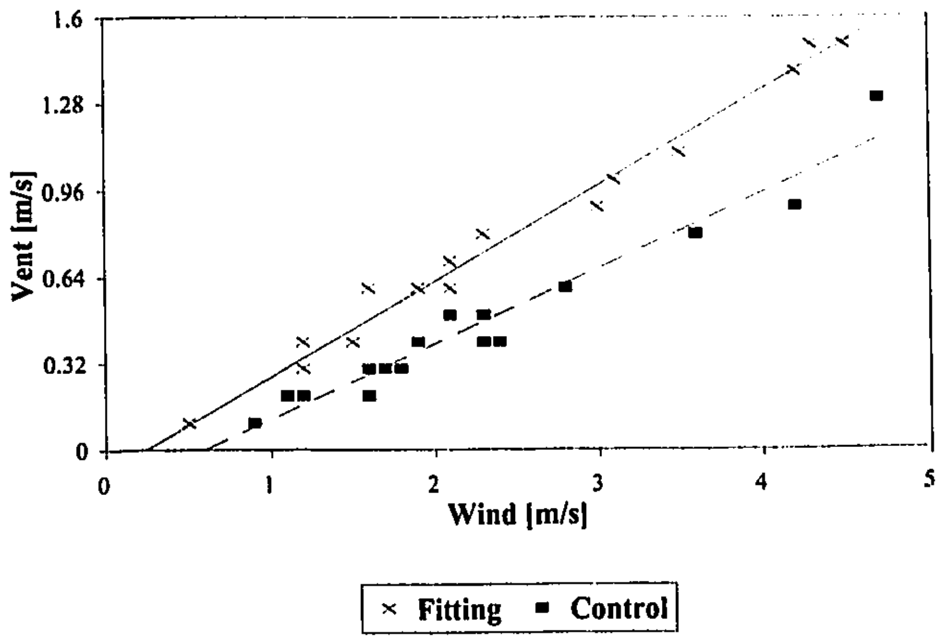


Figure 5.13
Venturi 15 cm : Ecole Tanghin Bloc B

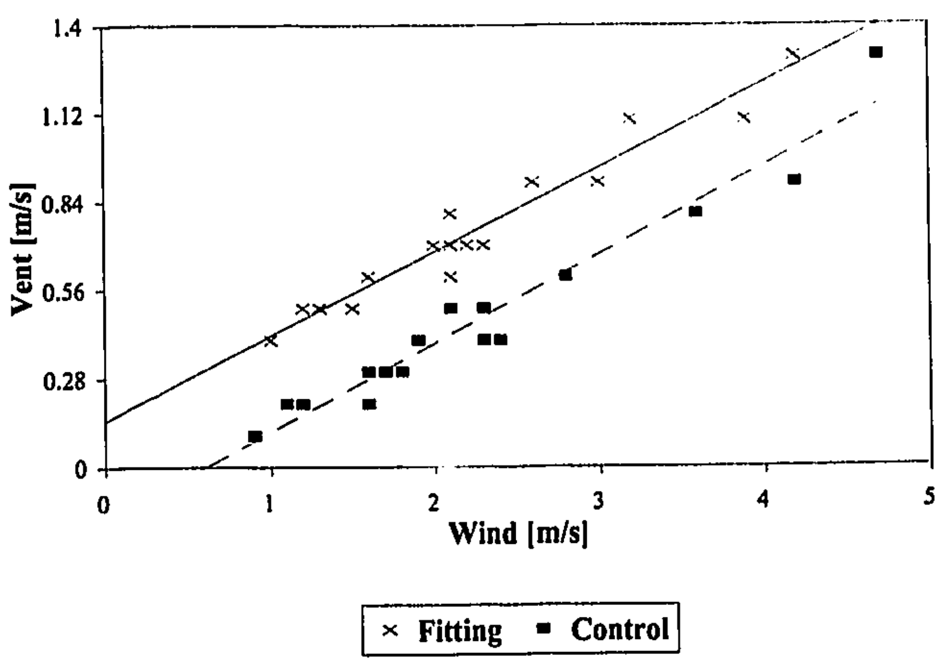


Figure 5.14
Venturi 10 cm : Ecole Tanghin Bloc B

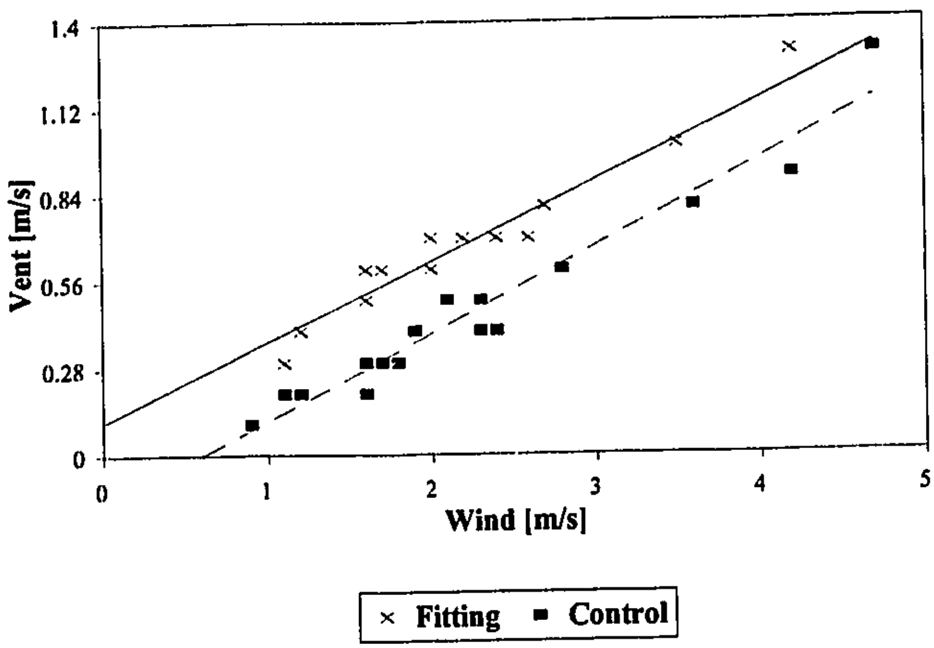


Figure 5.15
Topless Venturi : Ecole Tanghin Bloc B

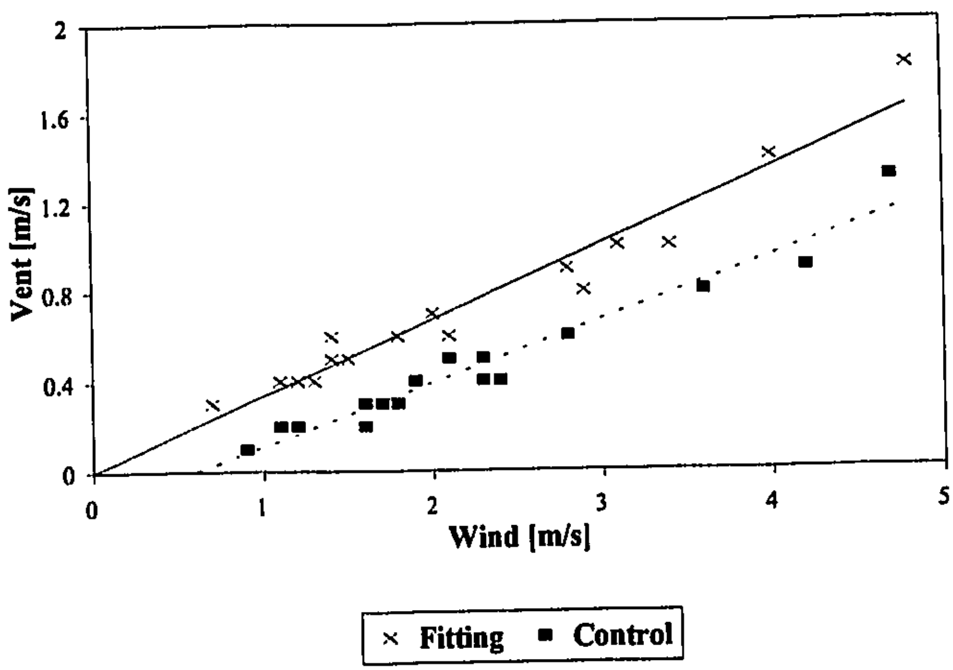


Figure 5.16
Venturi 10 cm : Ecole Dagnoin Bloc A

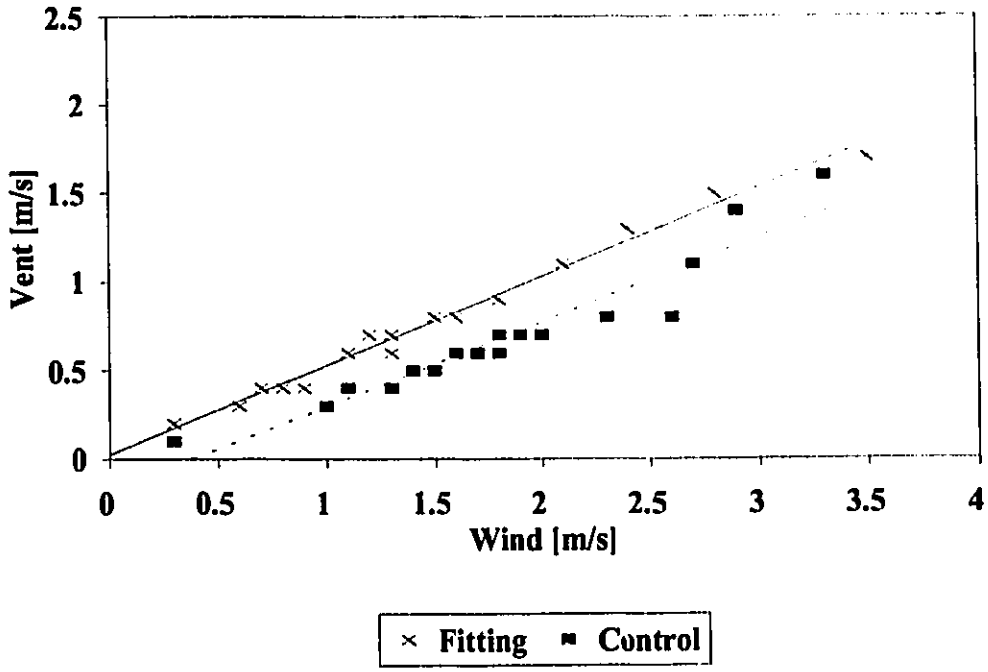
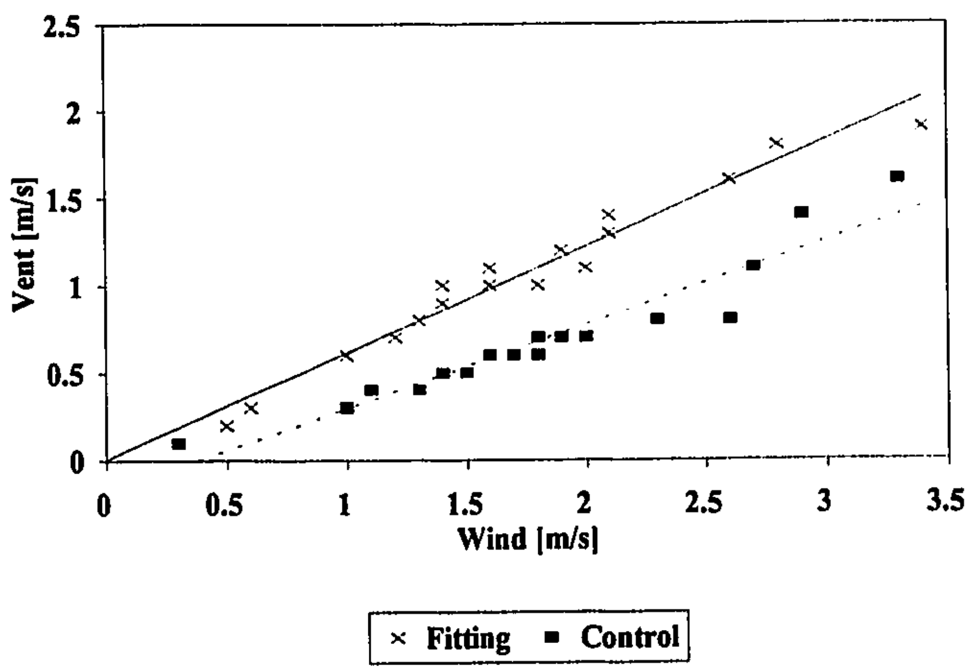


Figure 5.17
Single Venturi : Ecole Dagnoin Bloc A



5.3 Comparison of Laboratory and Field Results

5.3.1 Venturi Fitting

Comparing Figure 4.6 and Figures 5.12 to 5.17, the venturi tests in the field show the same general tendencies as the results of the laboratory tests. The field data shows that the induced flow rate increases at a linear rate with increased wind speed. The laboratory data shows a less linear relationship between induced ventilation flow and the wind speed above the pipe. This difference can be explained by the differences between the laboratory and field experiments as discussed below. In both cases, the venturi performance improves as the bowl separation increases and the single venturi produces the best increase in ventilation over the open pipe.

The one discrepancy between the two sets of results is that the laboratory fittings appear to be more effective at lower wind speeds with relative improvement over the open pipe falling off at higher wind speeds. The field data shows a fairly constant improvement for all wind speeds. This apparent discrepancy may be due to two causes. The laboratory fittings were tested without flyscreens in place. Analysis of loss over screens (Blevins 1984) shows that losses are greater at lower velocities. This reduced friction may have modified the performance of the fittings at lower velocities to enhance the ventilation improvement. Also, a wider range of wind speeds as was encountered in the field than was used in the laboratory, so the fitting performance for higher winds in the field cannot be properly compared to the laboratory results.

Despite this, it is apparent that the general behaviour of the venturi fitting was similar in the laboratory and in the field.

5.3.2 Slotted Fitting

The slotted Fitting also exhibits the same general characteristics for both the laboratory and the field tests. Referring to Figures 4.7 and 5.6 to 5.11, it can be seen that all the slotted fittings tested produce constantly increasing improvement in ventilation velocity over the open pipe. The slotted fittings perform worse than the open pipe below a threshold wind speed value, above which they show an improvement over the open pipe. The average threshold value in the field is 1.3 m/s while in the laboratory it was 0.7 m/s. This difference can again be explained by the fact that the fittings were tested without flyscreens in the laboratory which will have affected their performance at lower wind speeds.

5.3.3 Instrument Resolution

The hot wire anemometer probe used for the tests (Kane May KM4004) has a measurement range of 0 to 30 m/s with a resolution of 0.1 m/s. This instrument was chosen for its combination of ruggedness, portability and price, while still yielding acceptable precision.

Measurement of low velocity air flow with a hot wire anemometer is difficult due to the limits of the technology. Instruments are available which measure to a greater resolution but they are typically not as portable or robust enough to withstand the rigors of use in the field in Africa.

The resolution of 0.1 m/s clearly poses some problems for the measurement of small changes in velocity. This is most clearly seen in Figure 4.3 which shows the internal velocity profile within the laboratory ventpipe. The velocity profile is clearly not perfectly flat as measured by the anemometer, but varies continuously in a smooth curve to a maximum at the pipe centreline. There would also likely be small random fluctuations in the velocity profile. The instrument was not able to detect the small variations in velocity outside the boundary layer near the wall.

The instrument resolution is clearly a greater issue at lower velocities, when the measure velocities approach the resolution of the probe. For this reason, less confidence can be placed in the readings for which a low velocity was measured. Since low ventpipe velocities are associated with low winds, there is less certainty of the accessory performance at low wind speeds.

The probe resolution will probably have little effect on the general conclusions drawn from the data. Despite the small uncertainties inherent in the readings, it is clear that both the slotted and the venturi fittings produce an improvement over the open pipe. Where the resolution becomes more of an issue is in the conclusions concerning details of the fitting performance. This applies to the determination of the point at which the slotted fitting becomes more effective than the open pipe. In the field tests, the ventpipe velocities were on the order of 0.5 m/s near the cross-over point. Since the resolution of the anemometer is 0.1 m/s, the uncertainty in the velocity is ±0.05 m/s. This is significant and could affect the placement of the cross-over point. This effect is somewhat mitigated by the fact that a linear regression, which tends to average out errors, was used in determining the cross-over point. However, the fact remains that some error remains in the determination of the slotted fitting cross-over point. Therefore, some care should be taken when applying the criteria of a necessary wind of 1.3 m/s for an effective slotted fitting. In practice, it would be wise to consider applying a factor of safety to this figure when deciding on the feasibility of the slotted fitting.

Chapter Six

Sociological Considerations

6.1 Sociological Impact of Projects

An essential factor for consideration in any project in a developing country, is the interaction of the project and the people whom it is intended to serve. Engineers and economists unfamiliar with the customs and culture of the host country, may base their analyses on assumptions which, while valid in developed countries, may be completely inappropriate for a developing country. Failure to consider sociological and economic influences when dealing with an unfamiliar culture has lead in the past to projects which have not achieved the benefits desired, and have, in some cases, even worsened conditions in the receiving community. This experience has lead to an increased appreciation of the importance of sociological factors in the planning and design of development programmes.

In the past, water supply and sanitation projects were seen strictly as the domain of the engineer. Analysis of the influence of local culture and religion on the project was carried out,if at all, by the western-trained engineer. Typically, this training was insufficient to fully cope with the complexities of the situations presented to the designers. Recent workers (Elmendorf & Buckles 1980, Gamser 1988, Kandaŵire 1981) have begun to see the role which can be played by the social scientist. It is now recognized that all projects should include a social impact study carried out by people familiar with the society in question.

It is essential that the project complement the existing community organisation, and that it does not offend any religious or social taboos. This is especially important for sanitation projects. All societies have accepted practices and beliefs surrounding excreta and its disposal, and any project which does not take these into consideration is likely to be rejected by the community. It is equally important that the project be seen by the community as meeting a definite need. If not, there is a risk that the people will perceive the project as having been thrust upon them by outsiders, thus greatly reducing its likelihood of acceptance.

From this, it follows that there are three measures of feasibility which must be taken into account when evaluating a potential project. The first is technical feasibility, something which can be measured in a fairly straightforward way by an engineer given sufficient data. The second is economic feasibility; although economic data for developing countries can be difficult to gather or estimate the evaluation can be made with well-established techniques. The third, and arguably the most important measure, is that of social feasibility. This can be the most troublesome of the three to evaluate, given the difficulty in predicting human reactions to a new situation. Despite the difficulty, past experience has displayed the necessity of a social evaluation in development projects.

The most successful method of ensuring that the project is suitable for a given community is to involve the people at every decision point in the development of the project plan. People are asked what needs they see as most important in their community and are then asked to find, with outside assistance, the solution that they see as most appropriate. While successful, this process is time consuming and difficult to implement on a very large scale. It is, however, becoming more widely accepted as the best way to proceed with development efforts.

It is, therefore, obvious that any successful latrine installation programme must involve those being served, in all phases of its planning and implementation. CREPA is very aware of the importance of this and has two full time sociologists who work with community leaders to involve them in the project. Also, surveys and interviews are used to investigate the community's needs and their enthusiasm for the project under consideration. The staff of CREPA were, therefore, well equipped to aid in a socio-economic evaluation of the VIP ventilation improvement project.

The other aspects of the project dealing with the technical aspects of the project have been dealt with in earlier chapters. However thorough, this scientific analysis is not a complete evaluation of the project. A measure of the population's perception of the VIP latrine and associated problems must be undertaken to fully understand the viability of any attempt to improve the latrine.

6.2 Questionnaire Design

In order to fully evaluate the feasibility of the VIP latrine vent pipe additions, it was necessary to gather information on the attitudes of the population toward the latrines. The additions need not only to be technically effective, but must be accepted by the owners of the latrines. For this to happen, the owners must perceive a definite problem with the existing latrines and be willing and able to pay for the proposed improvements.

A questionnaire was designed with assistance of the CREPA staff sociologist to gather these data. The basic information to be collected was:

1) do the latrine owners perceive any odour problems with their VIP latrine?
2) how much would the owners be willing to pay to rectify the problem?
3) how much are the owners able to pay?

The last question is necessary because it has been found that people's expressed willingness to pay can depend not only on their ability to pay but on other factors such as the possibility of outside subsidies. If people perceive that an outside agency may be willing to pay for some of the project costs, they may lower the amount they are willing to pay. Conversely, if they perceive their community in competition with other communities for the project they may exaggerate their willingness to pay. In either case the figure provided by the community may not be a realistic estimate of how much of the cost the community is able to shoulder. A realistic estimate of their actual ability to pay a certain cost is needed to determine whether a project is possible; their willingness to pay this cost will indicate whether the community can be easily motivated to pay this amount.

Direct questioning would not differentiate between the family's ability to pay and their willingness to pay. Therefore the ability to pay was estimated by an inventory of the family's income and possessions such a bicycle, moped, running water and electricity. In this way it can be determined if the family's expressed willingness to pay is a realistic estimate of what is within the economic means of the family to pay.

The questionnaire was divided into three sections. The first section was concerned with socio-economic questions. These included the family's size, religion, ethnicity and economic situation. Much of this information, while of little direct use for this project, was collected because of its usefulness to CREPA in planning other projects. The second section dealt with questions concerning the family's VIP latrine and their opinion of how well it was operating. The third section was a physical examination of the latrine itself to determine how well it was built and maintained. The full questionnaire is displayed in Appendix F.

An important consideration to be taken into account when conducting a sociological survey is the choice of the questioners. If the questioner is perceived as an outsider, this fact may have an influence on the answers given by the respondents. It was decided that due to cultural and language barriers it was inappropriate for the author to conduct the questioning himself. The survey was carried out by two Mossé questioners whose first language was Morré, thus avoiding any problems of cultural acceptance by the respondents.

The questionnaire was conducted between June 15 and June 30 at forty-two households and institutions in Ouagadougou at which CREPA had assisted in the installation of a VIP latrine. Each household was visited by one of the two questioners and the survey questions were presented orally to the head of the household, who was in most cases male.

6.3 Questionnaire Results

The results of the questionnaire were taken from a sampling of forty-two households in Ouagadougou. This sample size is not sufficiently large for definite statistical inferences to be made with confidence. Additional data would most likely be necessary to make decisions involving significant financial investment. However, for the purposes of this project, this sample size is sufficient to discern the trends in the population's attitudes toward the VIP latrine, even though there may be some error associated with the statistics derived from the analysis.

When asked if they perceived any problems with their VIP latrine, 60 per cent of those surveyed reported problems. All of these reported strong odours as a problem. Other problems reported by some of the latrine owners were flies, ants and mosquito breeding. These data support the anecdotal reports received, that significant problems exist with the VIP latrine.

It is necessary to distinguish between those problems caused by insufficient ventilation and those caused by other reasons. For this, a physical examination of the latrines was needed. It was found that of those reporting odour problems, 12 per cent of the latrines were not being well maintained. Soiled squatting slabs and cracked or poorly placed cover slabs result in an obvious odour problem that increased ventilation will not be able to overcome. These problems must be rectified before it will be possible to see if odours remain beyond those caused by poor maintenance. Further, the problem of mosquito breeding, reported in 5 per cent of those surveyed, is a result of pit flooding. This is more a problem of poor latrine site selection or misuse of the latrine than a problem of latrine design.

Even after neglecting the latrines that were not well maintained, there remained 52 per cent of those surveyed who maintained their latrines well and were still experiencing odour problems. Since the latrine interior and superstructure is clean and well maintained, the only source of the odour in the superstructure is up from the pit through the squatting hole. This is a result of an insufficient flow rate venting air. All the latrines were built in exposed areas of the household compound so that sheltering of the ventpipe from the wind does not appear to be a contributing factor in these odour problems. It appears then, that these latrines could benefit from the increased ventilation rate provided by the vent pipe additions being investigated.

The next question investigated was that of the willingness of the latrine owners to pay for the improvement of their latrines. Each owner was asked to specify the range of range of costs (nil, 500 to 2500 CFA, 2500 to 5000 CFA etc.) he would be willing to pay to correct the odour problems in his latrine. Obviously, those owners who perceived no problems with their latrines were not willing to invest anything in its improvement. Even in the group which reported odour problems, 20 per cent said they would not be willing to pay for its improvement. Almost all (96 per cent) of the respondents who reported problems specified that they would not be willing to pay more than 5000 franc CFA (Cdn$ 14.50) for the improvement of their latrine. This indicates that if the vent pipe additions increase the latrine cost by more than 5000 franc CFA, it will be somewhat difficult to convince the owners to pay for the additions themselves.

The ability to pay for the latrine improvements was estimated by questioning the respondents concerning their monthly household expenses and possessions. The possessions such as running water, electricity and mopeds were listed as a check on the realism of the respondents estimate of monthly household expenses. Figure 6.1 displays the respondents' monthly

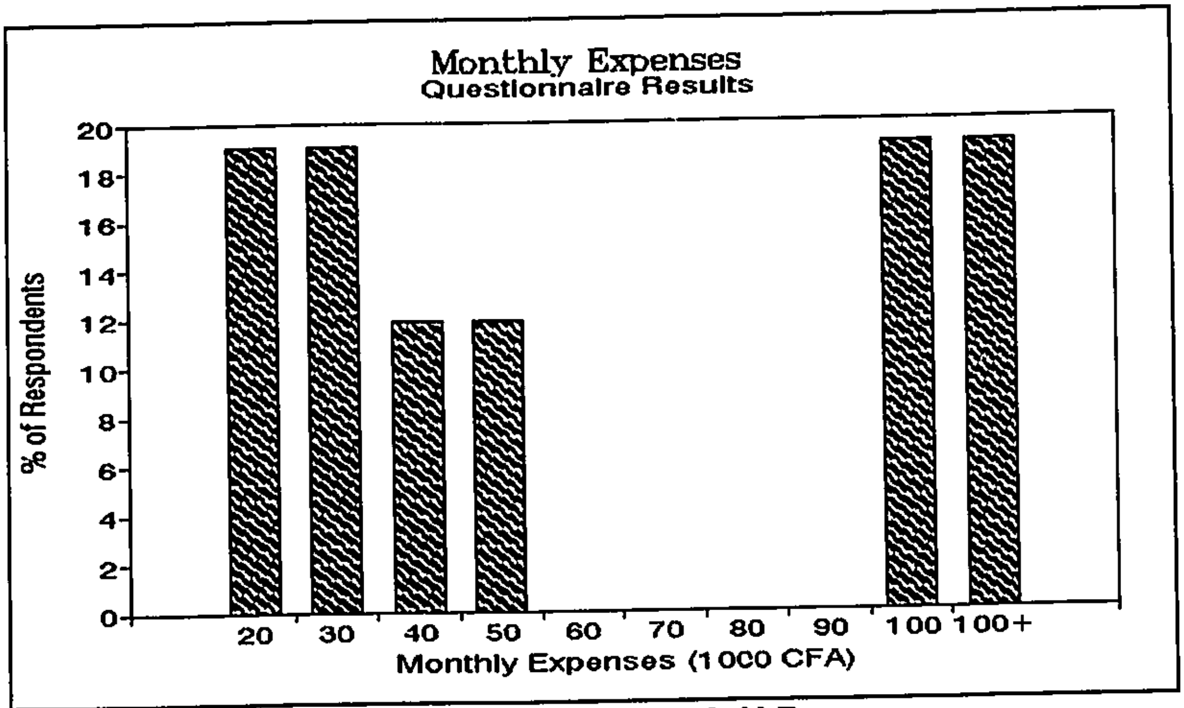


Figure 6.1 Household Expenses

household expenses. This is clearly a bimodal distribution: 62 per cent of the respondents have expenses of less than 50 000 CFA (Cdn$ 145) and 38 per cent have expenses of over 100 000 CFA (Cdn$ 290). This is a problem typical of populations in developing countries; that the distribution of wealth results in two quite disparate economic classes. This creates difficulties in making feasibility decisions since what is easily affordable for one section of the population may be an impossible burden for others.

It is difficult to decide on a reasonable amount to expect people to pay for the improvement of their latrines. Some workers in the field suggest that a reasonable amount to expect a population to pay for sanitation is 10 per cent of their annual income (Bourne 1984).

Considering that this is an improvement in an already existing sanitation system, a reasonable amount may be one per cent of the annual household expenses. This would result in a cost of 3000 CFA (US$ 8.70) for those in the lowest income group. This corresponds well to the 2500 CFA (US$ 7.25) that 20 per cent of the respondents gave as the maximum they would be willing to pay. This will obviously be less of a burden for those in the higher income groups. However, the problem of convincing the 20 per cent who were willing to pay nothing for improvements, still remains.

The results of the questionnaire provide information which must be taken into account when considering the feasibility of installing the vent pipe additions. The feasibility analysis is examined in Chapter 7.

Chapter Seven

Feasibility Analysis

When deciding whether the vent pipe additions can be recommended for widespread use, a number of factors must be considered. It is sometimes a problem in engineering analyses that the focus is too narrow and insufficient attention is given to nontechnical aspects of the project assessment. This is particularly important in the assessment of projects in developing countries where economic and social conditions can have a profound influence on the appropriateness of a given technology choice.

The first and most obvious factor to be considered is the technical effectiveness. To be considered for wider installation, the vent pipe additions must be shown to increase the rate of latrine ventilation. Further, the size of this increase must be determined and it must be understood under which conditions this increase is to be expected. Chapters 4 and 5 were devoted to the discussion of the investigation into the technical effectiveness of the proposed additions.

The socio-economic analysis is an important element of the evaluation of a potential project. If the project is seen by the target population as a useful step toward meeting a problem they see as a priority, then it is likely to meet with strong popular support. Without this support, the probability of affecting widespread change through the project is minimal. Further, it is essential that the programme be within the financial means of the population for its long-term viability to be secure.

7.1 Technical Feasibility

The primary purpose of this investigation was to determine the technical feasibility of the ventpipe additions. This involved determining which addition results in the greatest increase in ventilation rate over the open ventpipe. It was also important to delineate the range of conditions over which each addition was effective.

7.1.1 Efficiency of Additions

The experimental results showed quite conclusively that some, but not all, of the additions tested clearly improved the rate of ventilation through the VIP latrine. The improvement in ventilation depended on the wind speed under which the ventpipe was operating. In general, the greater the wind speed the greater will be the benefit gained through using the accessories. This is the case for both the venturi and the slotted accessories. The divergent accessory showed no significant improvement over the open pipe for any wind speed.

The venturi accessory showed an improvement ranging from 10 per cent under low wind conditions to approximately 37 per cent under relatively high wind conditions. This result is found for both the one bowl accessory and the two bowl accessory with a large bowl separation. So the venturi produces an improvement under all wind conditions.

The slotted accessory shows no improvement for wind speeds of less than 1.3 metres per second. In fact the accessory actually worsens the ventilation rate for these low wind conditions. However, for wind speeds greater than 1.3 meters per second, the slotted accessory shows an improvement in ventilation. Under high wind conditions, this improvement reaches up to a 52 per cent improvement over the open pipe.

These results then produce a choice between the venturi accessory which gives an improvement over all wind conditions and the slotted accessory which does not perform well in low winds but outperforms the venturi under high wind conditions. This is a choice which can only be made using climatic data for the area under consideration.

7.1.2 Climatic Factors

It is necessary to examine wind data to determine which accessory is best technically suited for a given area. Obviously, an area which rarely or never experiences winds above 2 metres per second would be unsuitable for the slotted accessory. An area which often has wind speeds of over this threshold would be a candidate for the slotted addition and the decision to implement the accessory would depend on other factors.

The Sahel region of Africa has quite good wind data available. The drought which began in the 1980's and the advancing desertification prompted the establishment of the Centre international pour la lutte contre la sécheresse sahélienne (CILSS). This centre instituted a programme to gather and analyze meteorological and hydrological data from eight Sahel countries including Burkina Faso. The results of this project have been published as a multi-volume atlas of the CILSS countries (AGRHYMET, 1988).

Included in the atlas is wind data taken at a 2 metre elevation at various stations throughout Burkina Faso. Figure 7.1 displays the probability of exceeding a given mean wind speed at four stations. From this it can be seen that all of the stations experience mean winds of over 1.3 metres per second for large portion of the year. At Ouagadougou the average wind speed is under 1.3 metres per second less than 5 per cent of the time. Bobo Dioulasso experiences slightly higher winds and has an mean wind of greater than 1.3 metres per second for almost the entire year. This means that for the majority of the time the slotted accessory would be effective for most cities in Burkina Faso.

From this it can be concluded that the slotted fitting is well suited to the wind conditions in Burkina Faso. Since wind conditions vary markedly with local geography and climate, it is possible that the conditions in other areas of Africa would be such that the slotted fitting

Figure 7.1
Mean Wind for Several Burkinabé Cities

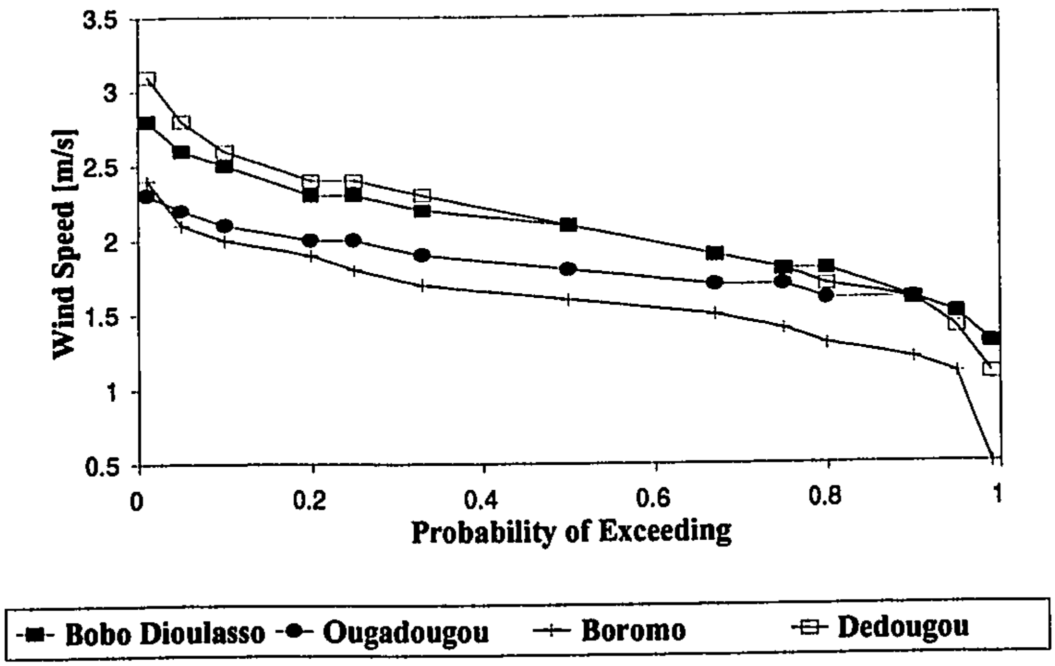
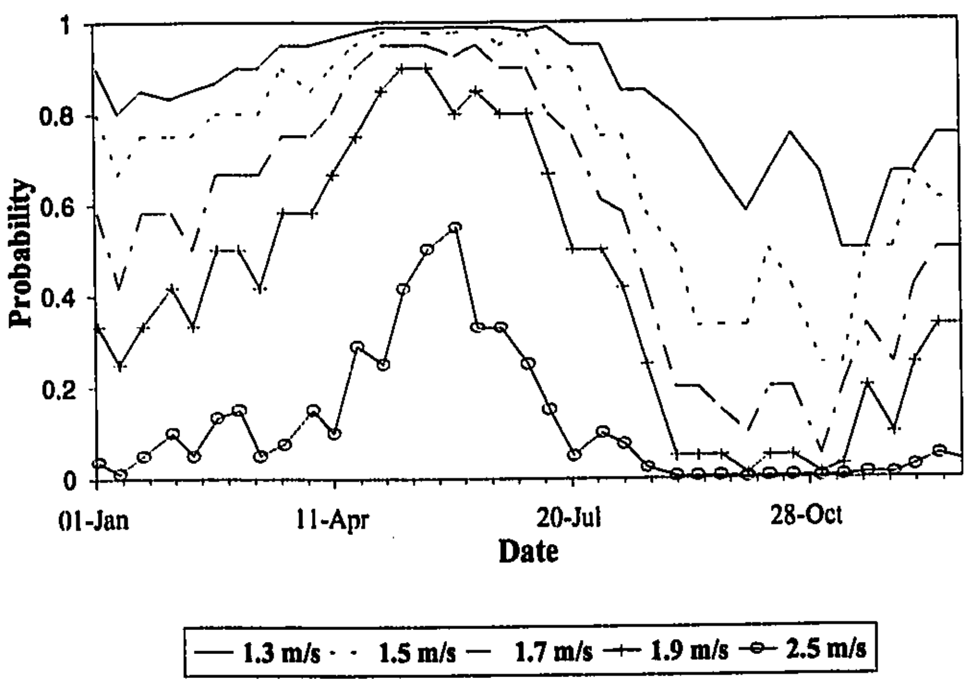


Figure 7.2: Ouagadougou Wind Speed
Probability of Exceeding Given Speed



would be suitable.

7.2 Socio-Economic Feasibility

All decision-making processes regarding the viability of an engineering project must take into account, in addition to the purely technical feasibility, the economics of the program. This is all the more true for programmes to be implemented in the developing world, where the economic conditions are such that cost can often make technology viable in the developed world impossible to implement.

7.2.1 Cost of Ventpipe Additions

In order to assess the economic viability of installing the vent pipe additions, it is important to know the added expense of the accessories to the cost of the basic latrine. The VIP latrine is only marginally affordable for most people in developing countries, and is beyond the means of many of the poorest. If the accessories add only a small percentage to the original cost, the added costs will probably not be a significant issue in the decision to proceed with the programme. However, if the additional costs represent a significant portion of the cost of the latrine the programme may not be economically viable.

Due to the devaluation of the franc CFA, there was some complication in determining the cost of VIP latrine construction. Records of construction costs were kept by CREPA for all of the latrine designs which have been built with the centre's assistance. However, these costs were all calculated using pre-devaluation material and labour prices, many of which have changed significantly with the currency devaluation. Since no latrines were actually built by CREPA after devaluation during this project, it was necessary to estimate the post-devaluation costs by using the itemized costs of previous latrine projects and substituting the present market values for the older costs for each item. The pre-devaluation cost information was taken from two project reports produced by CREPA (Pichonnat 1991, CREPA 1992).

The results of this cost estimation are presented in Appendix G. This shows that a single family alternating double pit VIP latrine, such as those installed in the private households which took part in the testing, would cost approximately 98 thousand francs CFA (Cdn$ 284) after devaluation. This is a cost increase of 58 per cent over the pre-devaluation cost. The same analysis shows that a communal latrine with nine cubical such as those constructed at Ecole Tanghin-Taambila would cost approximately 1.38 million francs CFA (Cdn$ 4000).

At first glance, it may seem that no economies of scale are apparent in the costs of the larger communal latrines. The nine cubical latrine blocs constructed at the schools cost more per cubical than the private single-family latrines. This is a result of the fact that the communal latrines are designed for a much greater rate of user traffic per cubical than the household latrines. This higher rate of use of the communal latrine blocks means that the cost per user is less than the cost per user for the private houses. These savings mean that in general, the communal VIP latrine block is the lowest cost sanitation technology for use in the developing world.

The communal latrines are built using more robust materials and the design includes features, such as doors and a privacy wall, not included in the family latrine design. Also, during the construction of a family latrine, labour costs are usually eliminated by using volunteer labour for most of the heavy work. This arrangement is not usually possible for the construction of communal latrines and paid labour must be used. Typically, institutions such as schools have greater access to funds for latrine construction than families, and can therefore consider the more expensive designs.

The fabrication cost of the ventpipe additions can be estimated from the cost of the accessories made for the ventilation tests. The expense of adding an addition to already existing latrines would likely be close to these costs. It can be expected that additions integrated into the latrine design and built with the latrine would cost less than this since the fabrication would be incorporated into the labour costs incurred for the bulk of the latrine.

The costs of the additions used in the tests and the percentage these costs represent of the total latrine cost are displayed in Table 7.1.

Table 7.1 Accessory Costs

	CFA	Cdn$	% cost
Double Venturi	1800	5.22	1.84
Single Venturi	600	1.74	0.61
Slotted	3250	9.42	3.32
Divergent	2000	5.80	2.04

From Table 7.1 it can be seen that even the most expensive addition represents less than a four per cent increase in the cost of the latrine. The single bowl venturi represents an almost negligible cost increase. All of these additions fall well below the 5000 franc CFA limit; the maximum most people claimed they would be willing to pay for an improvement to their latrine.

From the above discussion, it can be concluded that all the vent pipe additions considered in this project are economically feasible. Since they do not add significantly to the cost of building a latrine, it is likely that a latrine installation programme that was initially considered feasible will continue to be so after the added cost of the additions is considered.

Beyond the purely economic aspect, there are other important considerations with respect to the acceptability of a programme by the population it is to serve. A project must not be seen as forcing a solution to a problem that is not seen as important to the community. Therefore the survey results showing a significant minority (40 per cent) of those surveyed reporting no odour problems with their VIP latrine must be taken into account. So, while it will be possible to construct all new latrines with the ventpipe additions, the community attitude may make it impossible to undertake a comprehensive program of installation on existing latrines. These considerations are somewhat beyond the scope of this study but are nonetheless important in the overall design of a latrine installation program.

Taking into account the technical and economic factors considered above, the venturi fitting with only the single bowl appears to be the best of the accessories tested. It is similar in effectiveness to the venturi with a large bowl separation and avoids the problem of water ponding in the upper bowl which could provide a site for mosquito breeding. This, together with the significantly lower cost and ease of fabrication makes the single bowl venturi clearly superior.

Chapter Eight

Conclusion

8.1 Conclusions

The following conclusions can be drawn from the studies undertaken in this project:

·the divergent fitting produces no significant increase in ventilation rate over the open pipe

·the slotted fitting produces an increase in the ventilation rate for wind speeds of greater than 1.3 m/s

·the single bowl venturi fitting produces an increase in ventilation for all wind speeds, with greater increases observed at higher wind speeds

·the single bowl venturi fitting is significantly less expensive than either of the other fittings tested. The slotted and divergent fittings are 5.4 and 3.3 times the cost of the single venturi fitting respectively.

For the area under consideration in this study, Burkina Faso, the wind conditions are such that for the majority of the year the average wind is greater than the threshold value for effective performance of the slotted fitting. However,the significantly higher cost of the slotted fitting, may make it too expensive for widespread use. This is essentially an economic decision and must be made while taking into account factors which will be unique to each project under consideration. Given the conditions in Burkina Faso and the limited funds available for latrine improvement, the venturi fitting seems the most appropriate for wide spread installation.

It should be remembered that this conclusion is contingent on the wind conditions and economic factors of a given area. Thus for another region, the slotted fitting may be appropriate. Local data must be analyzed before that conclusion can be drawn.

8.2 Recommendations

8.2.1 Implementation of Accessories

One of the reasons for the success of the VIP latrine implementation programme during the years following its development was the standardized design of the main components. Technical drawings of the pit lining, cover slabs and superstructure were produced and widely distributed. This standardization allowed for more accurate material and cost estimates and improved the quality of the latrines built. The quality improvement gave the VIP a reputation for sturdiness and safety which was lacking in the unimproved pit latrine.

This leads to the conclusion that a successful implementation of the venturi ventpipe fitting must include a standardized design which could be easily incorporated into the existing VIP design plan. The fitting should be easy to produce and should be made of local materials to reduce costs.

A possible design of the fitting is shown in Figure 8.1. The exact size of the bowl and the material from which it is made will depend on the bowls which are easily available in the local markets. The use of a metal or plastic bowl, both easily available in the Ouagadougou central market, makes the fabrication of the fitting easy as the bottom of the bowl can be cut out and bent to hold the fitting in place. To form an effective venturi the bowl diameter should be approximately three times the pipe diameter or larger. Most VIP latrines are constructed with vent pipes of 200 mm diameter and would therefore require a bowl of around 600 mm diameter. As shown in the figure, this design allows for the fly screen to be easily held in place between the fitting and the pipe.

8.2.2 Research Recommendations

It would be useful to compile additional data on the performance of the single-bowl venturi fitting. Further work would not only be useful in corroborating this study's findings, it would also provide the opportunity to observe the venturi under a wider range of conditions. Follow-up studies would allow for a long term observation of the VIP latrine fitted with the venturi accessory, which due to time constraints, it was impossible to conduct during this study.

The limited scope of this project did not allow for an exhaustive study of the ways in which the ventilation through VIP latrines can be improved. The UN Technical Advisory Group which investigated VIP ventilation in the 1980's recommended that a number of other aspects of the system be studied.

The design of the superstructure is of obvious importance to the flow of air into the latrine pit. However little work has been done to optimize the design with respect to latrine ventilation. Aspects of superstructure design such as the placement of louvres and the design of doors are possibiiities which need further investigation. This is an area which may yield

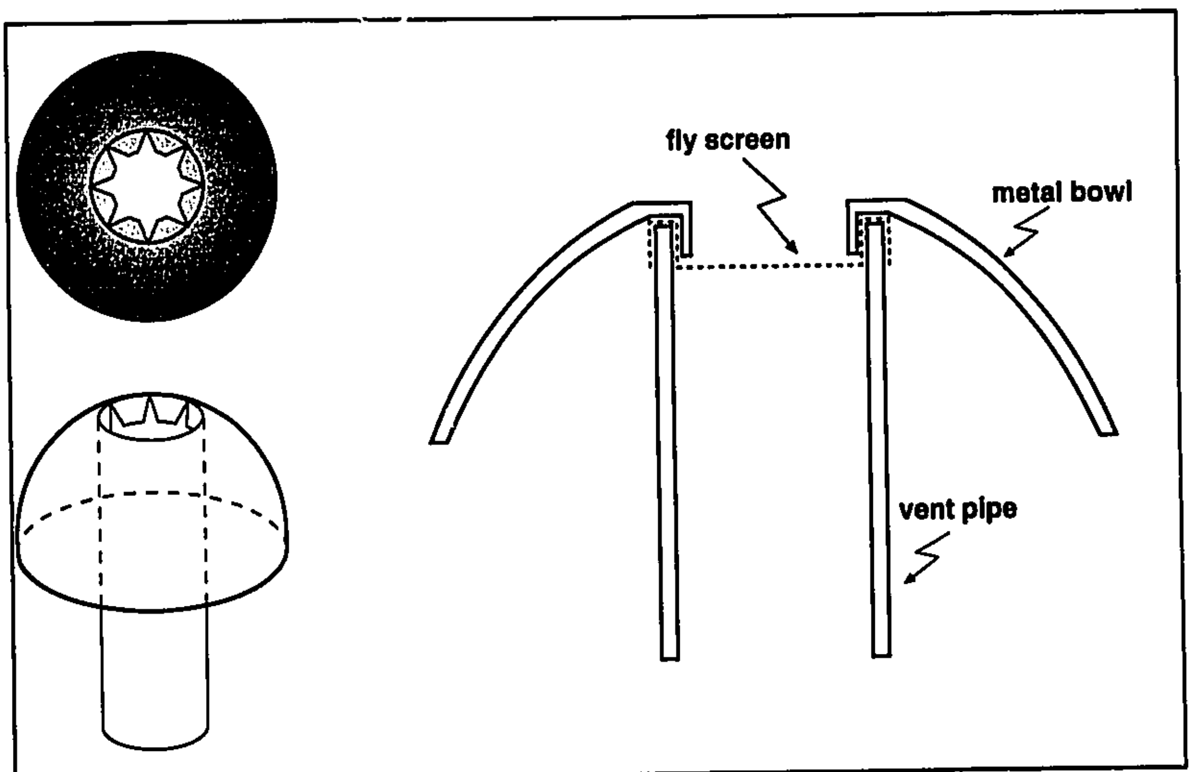


Figure 8.1 Venturi Design

important improvements in the design of the VIP latrine.

8.2.3 General Recommendations

During the process of this investigation the author had much opportunity to observe VIP latrines which had been in use for a number of years. It was found that a number of these had problems with their state of repair and maintenance. This was particularly true of the communal latrines, many of which were in such poor states of cleanliness that they were in themselves a health hazard. The management of communal latrines so as to maintain long term support for proper cleaning and maintenance has been a troublesome problem in many developing countries. Given that communal latrines are in many cases the only sanitation technology affordable for many communities, it is important to find solutions to this problem.

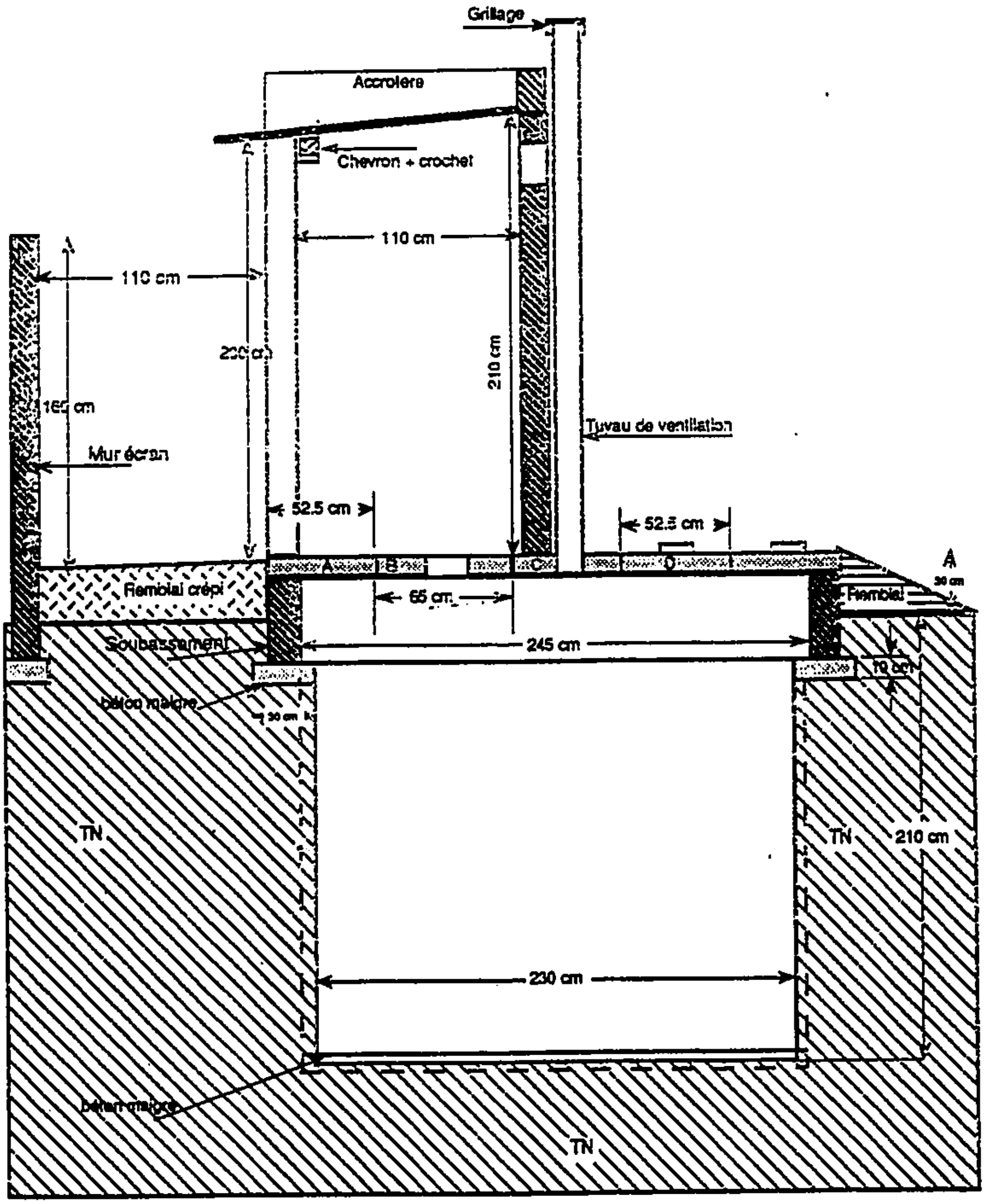
Appendix A: Anemometer Specifications

Model: Kane May KM4004 hot wire anemometer

Measurement Range	Air Velocity	0 to 30 m/s
	Air Temperature	-10 °C to 70 °C
Accuracy	Air Velocity	± 3% of reading
	Air Temperature	± 0.1 °C
Resolution	Air Velocity	0.1 m/s
	Air Temperature	0.1 °C

Appendix B: Latrine Design Plans

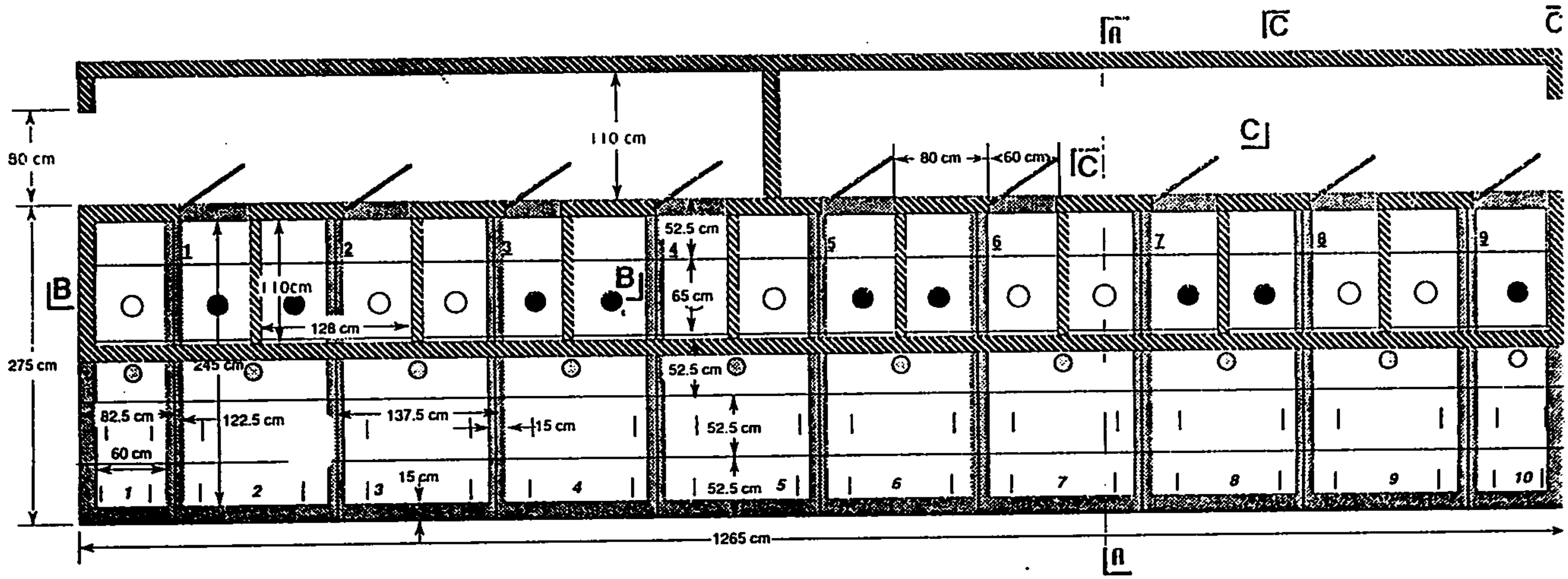
Coupe A-A



LEGENDE

A,B,C Dalles

VUE EN PLAN



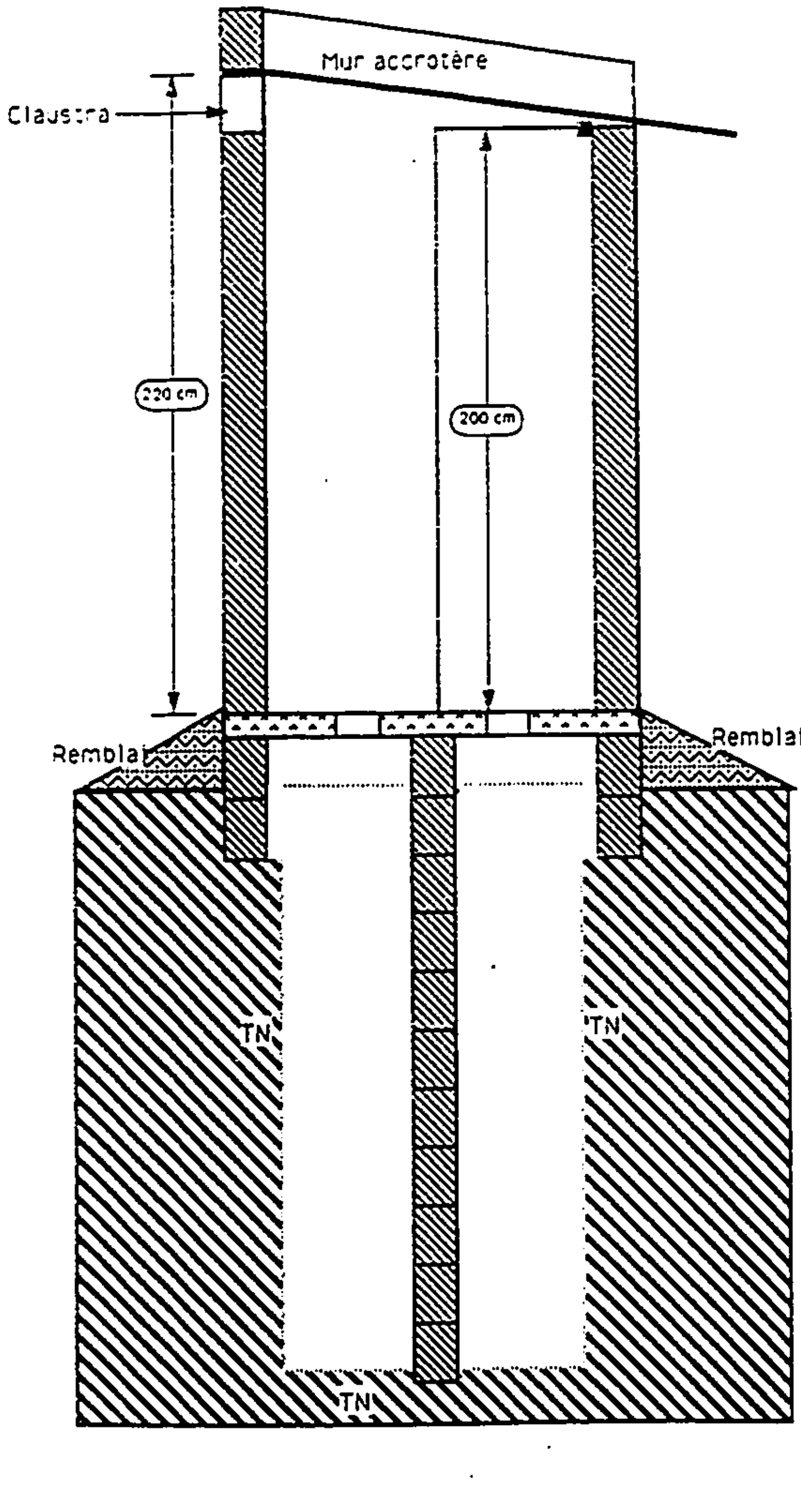
Légende

- ○ Trou de défécation ouverts
- ● Trou de défécation fermé
- ◎ Trou pour tuyaux de ventilation
- 1 2 Cabines
- *1 2* Fosses
- ▨ Mur en parpaing de 15
- ▨ - de 10

CREPA / Service technique

VIP publique pour l'ecole primaire de tanghin tanbila (1000 élèves).
Sept - oct 90.

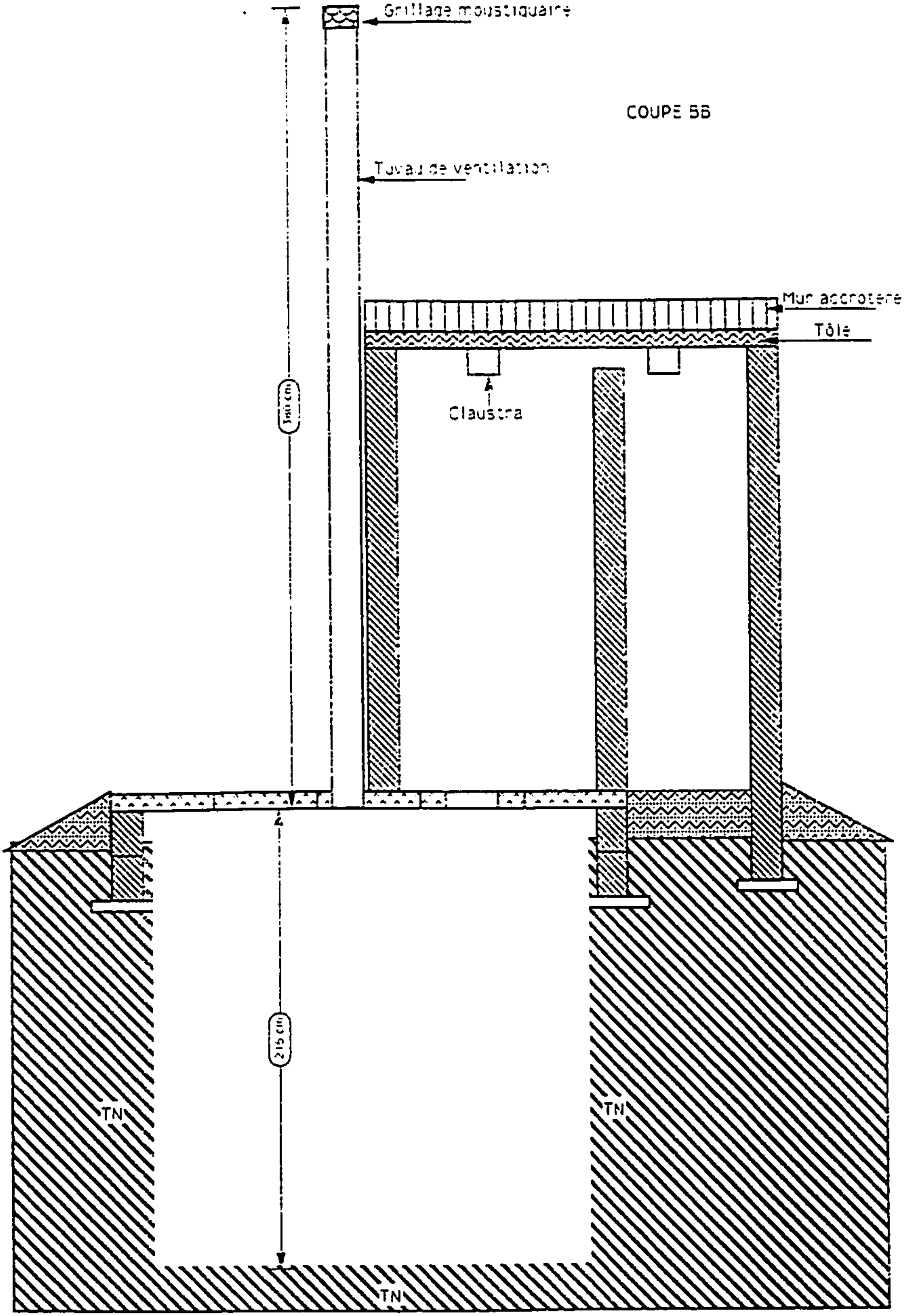
COUPE A7



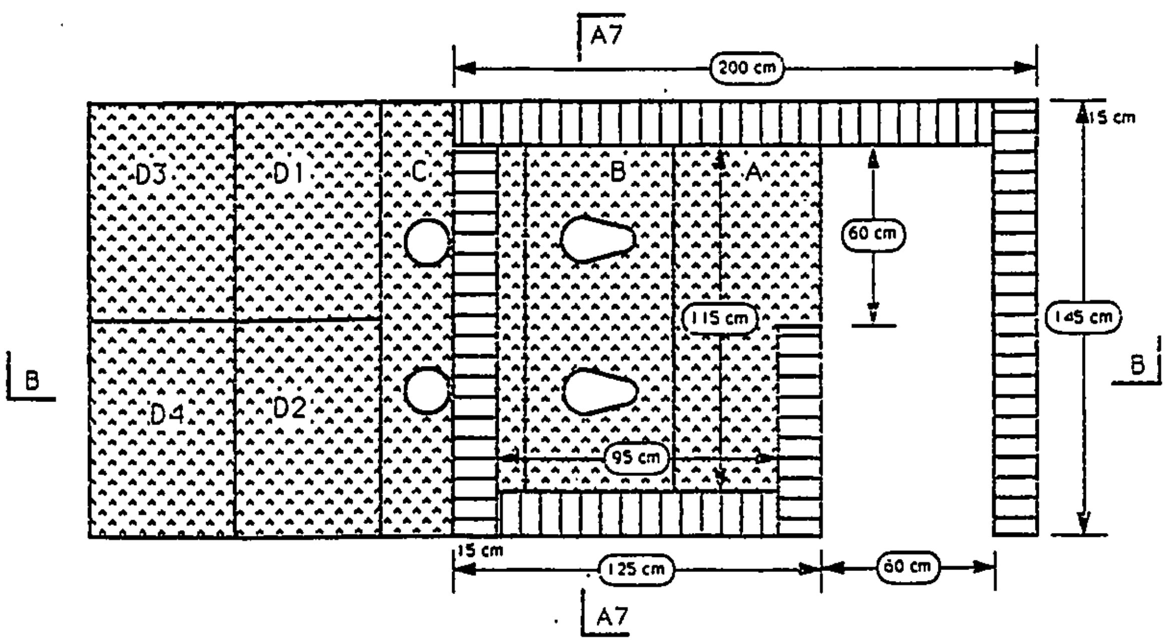
CREPA / SERVICE TECHNIQUE
Formation artisans burkinabé
Plan de vip familial : folio 8
E = 1/25 Juillet 1991

CREPA / SERVICE TECHNIQUE
Formation artisans burkinabé
Plan de vip familial : folio 9
E = 1/25 Juillet 1991

COUPE BB



9) Dimensions de la cabine



CREPA / SERVICE TECHNIQUE
Formation artisans burkinabé
Plan de vip familial : folio 7
E = 1/25 Juillet 1991

Appendix C: Laboratory Test Results

Data from Ventpipe Velocity Trials

Equipment: Hotwire anamometer
Inner Pipe Diameter 5.5 in
139.59 mm

Pipe Area 15304.63 mm^2
0.015305 m^2

1. Fan speed wind velocities [m/s]

Fan Speed	mm above pipe outlet 0	50	100	150	200	250	Average m/s
1 low	0.1	0.1	0.1	0.2	0.2	0.2	0.15
1 high	0.3	0.4	0.4	0.4	0.5	0.5	0.42
2 low	1.3	1.3	1.3	1.4	1.4	1.5	1.36
2 med	1.6	1.7	1.7	1.7	1.7	1.8	1.70
2 high	1.8	1.9	2.1	2.0	2.0	2.1	1.98

2. Check of Centreline Velocity Representivity

Fan speed: 2 low with open pipe

Distance from wall mm	Velocity m/s	Distance Ratio r/ro	Velocity Ratio V/Vcl
0	0	0.000	0.00
3	0.2	0.043	0.67
5	0.3	0.071	1.00
10	0.3	0.143	1.00
20	0.3	0.286	1.00
30	0.3	0.429	1.00
40	0.3	0.571	1.00
50	0.3	0.714	1.00
60	0.3	0.857	1.00
70	0.3	1.000	1.00

To calculate volume flowrate (Q), the pipe area can be divided into three zones

Zone 1: the ring from the wall to 3 mm from wall
Zone 2: the ring from 3 mm from wall to 5 mm from wall
Zone 3: the circle from the centreline to 5 mm from the wall

The velocity for each zone is taken as the average of the boundary velocities for that zone

Zone	Area m^2	Velocity m/s	Flowrate m^3/s
1	0.00129	0.10	0.00013
2	0.00083	0.25	0.00021
3	0.01319	0.30	0.00396
Total	0.01530	-	0.00429

Average Velocity	0.280	m/s
Centreline velocity	0.300	m/s
% difference	6.51%	

Velocity Tests

Open Pipe			
Fan Speed	Velocity m/s	Flowrate m^3/h	Reynolds Number
1 low	0.20	11.019	1849
1 high	0.25	13.774	2311
2 low	0.30	16.529	2773
2 med	0.45	24.793	4160
2 high	0.55	30.303	5085

Venturi Fitting

Venturi 25 mm bowl Separation			
Fan Speed	Veloctiy m/s	Flowrate m³/h	Reynolds Number
1 low	0.20	11.019	1849
1 high	0.25	13.774	2311
2 low	0.25	13.774	2311
2 med	0.30	16.529	2773
2 high	0.35	19.284	3236

Venturi 50 mm bowl Separation			
Fan Speed	Veloctiy m/s	Flowrate m³/h	Reynolds Number
1 low	0.20	11.019	1849
1 high	0.25	13.774	2311
2 low	0.30	16.529	2773
2 med	0.35	19.284	3236
2 high	0.40	22.039	3698

Venturi 75 mm bowl Separation			
Fan Speed	Veloctiy m/s	Flowrate m³/h	Reynolds Number
1 low	0.25	13.774	2311
1 high	0.35	19.284	3236
2 low	0.40	22.039	3698
2 med	0.45	24.793	4160
2 high	0.50	27.548	4622

Venturi 100 mm bowl Separation			
Fan Speed	Veloctiy m/s	Flowrate m³/h	Reynolds Number
1 low	0.30	16.529	2773
1 high	0.40	22.039	3698
2 low	0.40	22.039	3698
2 med	0.40	22.039	3698
2 high	0.50	27.548	4622

Single Venturi			
Fan Speed	Veloctiy m/s	Flowrate m³/h	Reynolds Number
1 low	0.35	19.284	3236
1 high	0.45	24.793	4160
2 low	0.45	24.793	4160
2 med	0.50	27.548	4622
2 high	0.60	33.058	5547

Slotted Fitting

Slotted with Top			
Fan Speed	Veloctiy m/s	Flowrate m³/h	Reynolds Number
1 low	0.10	5.510	924
1 high	0.15	8.264	1387
2 low	0.45	24.793	4160
2 med	0.50	27.548	4622
2 high	0.65	35.813	6009

Slotted without Top			
Fan Speed	Veloctiy m/s	Flowrate m³/h	Reynolds Number
1 low	0.15	8.264	1387
1 high	0.20	11.019	1849
2 low	0.50	27.548	4622
2 med	0.55	30.303	5085
2 high	0.60	33.058	5547

Smoke Tests

Open Pipe				
Fan Speed	Trial 1 s	Trial 2 s	Average s	Velocity m/s
Off	6.0	5.2	5.600	0.325
2 low	4.5	4.2	4.350	0.418
2 med	4.0	4.4	4.200	0.433
2 high	3.6	4.0	3.800	0.479

Slotted with Top				
Fan Speed	Trial 1 s	Trial 2 s	Average s	Velocity m/s
Off	6.4	5.8	6.100	0.298
2 low	4.6	5.4	5.000	0.364
2 med	3.8	4.1	3.950	0.461
2 high	3.2	3.6	3.400	0.535

Venturi 50 mm Separation				
Fan Speed	Trial 1 s	Trial 2 s	Average s	Velocity m/s
Off	6.2	5.8	6.000	0.303
2 low	4.1	3.6	3.850	0.473
2 med	2.4	3.2	2.800	0.650
2 high	1.9	2.1	2.000	0.910

Appendix D: Field Test Results

The following abbreviations are used in the presentation of the field data

Ambient Conditions	o.c. 25%	overcast 25% cloud cover
	o.c. 100%	overcast full cloud cover
Wind Direction	l	wind approaching from left of latrine
	r	wind approaching from right of latrine
	f	wind approaching from latrine front
	b	wind approaching from lartrine back

Ecole Tanghin-Taambila Bloc A

Tanghin- Taambila A1 Control							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.4	40.1	37.4	1.3	l
04-Mar	o.c. 25%	29.8	0.5	30.7	32.9	1.4	b
07-Mar	cloudless	33.3	0.3	34.6	32.9	1.0	l
11-Mar	o.c. 25%	33.8	0.6	34.6	locked	1.9	b
23-Mar	o.c. 50%	40.1	0.1	36.6	locked	0.3	b
05-Apr	o.c. 25%	32.0	0.9	31.0	2.2	2.2	f
08-Apr	cloudless	33.7	0.8	31.5	31.8	2.8	r
11-Apr	cloudless	36.7	0.5	36.6	36.8	1.8	l
15-Apr	cloudless	33.6	1.2	32.9	34.9	3.8	r
18-Apr	cloudless	36.5	1.1	36.4	37.3	2.5	f
22-Apr	cloudless	33.5	0.7	33.1	34.8	1.8	f
26-Apr	cloudless	33.4	1.0	33.5	33.8	3.0	r
29-Apr	cloudless	35.6	1.3	35.0	35.4	4.2	r
03-May	o.c. 25%	30.7	0.7	30.9	30.7	2.2	r
06-May	o.c. 100%	30.3	0.5	30.3	30.1	1.1	f
09-May	cloudless	37.3	0.8	37.9	38.8	2.1	f
13-May	o.c. 100%	30.3	0.3	30.3	30.5	1.0	r
16-May	cloudless	34.5	0.6	34.5	35.3	2.1	r
20-May	cloudless	31.6	0.6	32.4	32.9	2.1	b
23-May	cloudless	31.0	0.8	31.0	31.2	2.6	r
27-May	cloudless	32.6	1.1	31.9	32.2	4.0	b
30-May	o.c. 100%	29.9	0.4	30.0	30.2	1.5	r
03-Jun	cloudless	33.8	0.7	33.5	33.2	2.5	b
15-Jun	cloudless	29.2	0.4	29.0	29.2	1.1	b
17-Jun	cloudless	32.7	0.8	32.8	32.5	3.0	b
20-Jun	cloudless	29.9	0.5	32.1	32.2	1.9	r
27-Jun	cloudless	30.2	0.9	29.5	29.6	3.8	b
04-Jul	cloudless	29.7	0.1	29.8	29.4	0.1	f
11-Jul	cloudless	32.5	0.7	32.2	32.3	2.5	r
15-Jul	cloudless	30.9	0.7	30.5	30.6	2.8	b
18-Jul	o.c. 100%	28.1	0.6	27.7	27.5	2.3	r
22-Jul	o.c. 100%	28.5	0.3	27.6	27.7	1.2	l

Tanghin-Taambila A2 Divergent 25 cm							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.3	38.5	37.4	1.1	l
04-Mar	o.c. 25%	29.8	0.7	31.6	32.9	2.7	b
07-Mar	cloudless	33.3	0.4	35.2	32.9	1.2	l
11-Mar	o.c. 25%	33.8	0.5	35.0	35.8	1.6	b
23-Mar	o.c. 50%	40.1	0.1	38.3	locked	0.4	b
05-Apr	o.c. 25%	32.0	0.9	31.6	locked	2.2	f
08-Apr	cloudless	33.7	0.4	31.8	31.8	1.8	r
11-Apr	cloudless	36.7	0.5	36.8	36.8	1.5	l
15-Apr	cloudless	33.6	0.7	33.6	34.9	1.9	r
18-Apr	cloudless	36.5	0.0	36.5	37.3	0.0	f
22-Apr	cloudless	33.5	0.5	33.9	34.8	1.1	f
26-Apr	cloudless	33.4	0.4	34.1	33.8	1.8	r
29-Apr	cloudless	35.6	1.3	35.8	35.4	4.5	r
03-May	o.c. 25%	30.7	0.1	31.0	30.7	0.4	r
06-May	o.c. 100%	30.3	0.4	30.4	30.1	1.1	f
09-May	cloudless	37.3	0.5	38.2	38.8	1.2	f
13-May	o.c. 100%	30.3	0.3	30.4	30.5	1.1	r
16-May	cloudless	34.5	0.4	35.0	35.3	1.3	r
20-May	cloudless	31.6	0.5	32.8	32.9	1.9	b
23-May	cloudless	31.0	1.3	31.2	31.2	3.9	r
27-May	cloudless	32.6	1.3	31.9	32.2	5.3	b
30-May	o.c. 100%	29.9	0.2	30.0	30.2	1.3	r
03-Jun	cloudless	33.8	0.8	33.2	33.2	3.4	b
15-Jun	cloudless	29.2	1.0	29.4	29.2	4.0	b
17-Jun	cloudless	32.7	0.2	32.9	32.5	0.9	b
20-Jun	cloudless	29.9	1.2	31.6	32.2	3.5	r
27-Jun	cloudless	30.2	0.6	29.4	29.6	1.8	b
04-Jul	cloudless	29.7	0.6	29.7	29.4	1.7	f
11-Jul	cloudless	32.5	0.7	32.1	32.3	2.2	r
15-Jul	cloudless	30.9	0.6	30.5	30.6	2.0	b
18-Jul	o.c. 100%	28.1	0.2	27.7	27.5	1.3	r
22-Jul	o.c. 100%	28.5	0.9	27.1	27.7	2.6	l

Tanghin-Taambila A3 Divergent 35 cm							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.5	37.0	37.4	1.3	l
04-Mar	o.c. 25%	29.8	0.4	31.2	32.9	1.0	b
07-Mar	cloudless	33.3	0.6	35.6	32.9	1.9	l
11-Mar	o.c. 25%	33.8	0.4	34.9	35.8	0.8	b
23-Mar	o.c. 50%	40.1	0.1	39.5	locked	0.4	b
05-Apr	o.c. 25%	32.0	1.2	31.5	locked	2.9	f
08-Apr	cloudless	33.7	0.4	31.8	31.8	1.6	r
11-Apr	cloudless	36.7	0.9	37.0	36.8	2.8	l
15-Apr	cloudless	33.6	0.5	33.7	34.9	1.4	r
18-Apr	cloudless	36.5	0.4	37.6	37.3	0.9	f
22-Apr	cloudless	33.5	0.2	34.5	34.8	0.4	f
26-Apr	cloudless	33.4	0.1	34.4	33.8	0.3	r
29-Apr	cloudless	35.6	0.8	35.4	35.4	2.2	r
03-May	o.c. 25%	30.7	1.2	30.5	30.7	4.0	r
06-May	o.c. 100%	30.3	0.3	30.3	30.1	1.0	f
09-May	cloudless	37.3	0.8	38.1	38.8	2.0	f
13-May	o.c. 100%	30.3	0.4	30.6	30.5	1.0	r
16-May	cloudless	34.5	0.8	35.1	35.3	2.6	r
20-May	cloudless	31.6	0.5	32.5	32.9	1.6	b
23-May	cloudless	31.0	1.2	31.2	31.2	3.8	r
27-May	cloudless	32.6	0.2	32.1	32.2	0.7	b
30-May	o.c. 100%	29.9	0.3	30.3	30.2	1.3	r
03-Jun	cloudless	33.8	0.7	33.5	33.2	3.2	b
15-Jun	cloudless	29.2	0.7	29.4	29.2	2.1	b
17-Jun	cloudless	32.7	1.1	32.4	32.5	4.2	b
20-Jun	cloudless	29.9	0.7	31.6	32.2	2.0	r
27-Jun	cloudless	30.2	1.2	29.4	29.6	4.3	b
04-Jul	cloudless	29.7	0.5	29.6	29.4	1.2	f
11-Jul	cloudless	32.5	0.8	32.1	32.3	2.4	r
15-Jul	cloudless	30.9	0.6	30.6	30.6	2.3	b
18-Jul	o.c. 100%	28.1	0.6	27.6	27.5	2.2	r
22-Jul	o.c. 100%	28.5	0.6	27.4	27.7	2.4	l

Tanghin-Taambila A4 Slotted Without Top							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.4	37.8	37.4	1.0	l
04-Mar	o.c. 25%	29.8	0.3	31.6	32.9	1.6	b
07-Mar	cloudless	33.3	0.4	35.3	32.9	1.7	l
11-Mar	o.c. 25%	33.8	0.3	36.2	35.8	1.5	b
23-Mar	o.c. 50%	40.1	0.2	39.6	locked	1.0	b
05-Apr	o.c. 25%	32.0	1.8	31.7	locked	3.2	f
08-Apr	cloudless	33.7	0.6	31.8	31.8	2.0	r
11-Apr	cloudless	36.7	0.8	37.5	36.8	2.8	l
15-Apr	cloudless	33.6	1.0	33.9	34.9	2.5	r
18-Apr	cloudless	36.5	1.0	37.7	37.3	2.0	f
22-Apr	cloudless	33.5	0.1	34.9	34.8	0.6	f
26-Apr	cloudless	33.4	0.3	34.5	33.8	1.4	r
29-Apr	cloudless	35.6	1.8	35.5	35.4	3.8	r
03-May	o.c. 25%	30.7	2.0	31.0	30.7	4.6	r
06-May	o.c. 100%	30.3	0.4	30.6	30.1	1.3	f
09-May	cloudless	37.3	0.3	38.9	38.8	0.9	f
13-May	o.c. 100%	30.3	0.4	30.7	30.5	1.8	r
16-May	cloudless	34.5	1.7	35.2	35.3	3.5	r
20-May	cloudless	31.6	0.4	32.9	32.9	1.8	b
23-May	cloudless	31.0	1.1	31.5	31.2	2.6	r
27-May	cloudless	32.6	1.2	32.1	32.2	3.2	b
30-May	o.c. 100%	29.9	0.3	30.3	30.2	1.1	r
03-Jun	cloudless	33.8	1.1	33.6	33.2	2.9	b
15-Jun	cloudless	29.2	1.8	29.5	29.2	4.9	b
17-Jun	cloudless	32.7	1.5	32.7	32.5	4.0	b
20-Jun	cloudless	29.9	0.7	31.6	32.2	2.0	r
27-Jun	cloudless	30.2	1.4	29.2	29.6	3.9	b
04-Jul	cloudless	29.7	0.6	29.7	29.4	1.6	f
11-Jul	cloudless	32.5	0.5	32.8	32.3	1.9	r
15-Jul	cloudless	30.9	0.6	30.6	30.6	2.1	b
18-Jul	o.c. 100%	28.1	1.9	27.5	27.5	4.2	r
22-Jul	o.c. 100%	28.5	0.9	26.8	27.7	2.4	l

Tanghin-Taambila A5 Slotted With Top							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.1	38.4	37.4	1.0	l
04-Mar	o.c. 25%	29.8	0.3	31.7	32.9	1.2	b
07-Mar	cloudless	33.3	1.4	33.6	32.9	3.4	l
11-Mar	o.c. 25%	33.8	0.2	35.9	35.8	1.1	b
23-Mar	o.c. 50%	40.1	0.1	40.1	locked	0.7	b
05-Apr	o.c. 25%	32.0	0.6	31.9	locked	1.8	f
08-Apr	cloudless	33.7	0.4	31.8	31.8	1.6	r
11-Apr	cloudless	36.7	0.5	37.4	36.8	1.8	l
15-Apr	cloudless	33.6	0.5	33.9	34.9	1.8	r
18-Apr	cloudless	36.5	0.8	37.7	37.3	2.1	f
22-Apr	cloudless	33.5	0.3	35.1	34.8	1.0	f
26-Apr	cloudless	33.4	1.1	34.9	33.8	2.7	r
29-Apr	cloudless	35.6	1.2	35.7	35.4	2.8	r
03-May	o.c. 25%	30.7	0.6	31.0	30.7	1.9	r
06-May	o.c. 100%	30.3	0.8	30.6	30.1	2.0	f
09-May	cloudless	37.3	0.2	39.0	38.8	0.7	f
13-May	o.c. 100%	30.3	0.3	30.8	30.5	1.3	r
16-May	cloudless	34.5	0.2	35.2	35.3	1.2	r
20-May	cloudless	31.6	0.3	33.1	32.9	1.3	b
23-May	cloudless	31.0	1.6	31.4	31.2	4.0	r
27-May	cloudless	32.6	0.9	32.5	32.2	2.7	b
30-May	o.c. 100%	29.9	1.3	30.6	30.2	3.0	r
03-Jun	cloudless	33.8	0.4	33.5	33.2	1.1	b
15-Jun	cloudless	29.2	1.1	29.8	29.2	3.0	b
17-Jun	cloudless	32.7	1.2	32.4	32.5	3.4	b
20-Jun	cloudless	29.9	1.6	31.6	32.2	3.7	r
27-Jun	cloudless	30.2	0.8	29.1	29.6	2.0	b
04-Jul	cloudless	29.7	0.6	29.6	29.4	1.7	f
11-Jul	cloudless	32.5	1.9	32.9	32.3	4.5	r
15-Jul	cloudless	30.9	0.4	30.7	30.6	1.6	b
18-Jul	o.c. 100%	28.1	0.7	27.6	27.5	2.2	r
22-Jul	o.c. 100%	28.5	0.7	26.8	27.7	2.4	l

Ecole Tanghin-Taambila Bloc B

Tanghin- Taambila B1 Venturi 20cm separation							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.6	37.1	locked	1.6	l
04-Mar	o.c. 25%	29.8	0.6	33.0	30.7	1.7	b
07-Mar	cloudless	33.3	0.4	33.6	34.3	1.2	l
11-Mar	o.c. 25%	33.8	1.2	35.3	locked	4.0	b
23-Mar	o.c. 50%	40.1	0.5	40.0	locked	1.2	b
05-Apr	o.c. 25%	33.9	1.2	33.6	locked	2.4	f
08-Apr	cloudless	33.7	0.1	33.4	32.9	0.5	r
11-Apr	cloudless	37.3	0.2	37.3	37.2	1.1	l
15-Apr	cloudless	35.9	0.4	35.2	34.8	1.5	r
18-Apr	cloudless	36.5	0.3	38.0	38.6	0.1	f
22-Apr	cloudless	37.1	1.0	36.0	36.4	1.8	f
26-Apr	cloudless	33.4	0.9	35.1	35.8	3.0	r
29-Apr	cloudless	35.6	1.4	35.9	36.7	4.2	r
03-May	o.c. 25%	30.7	1.0	31.6	31.0	3.1	r
06-May	o.c. 100%	30.3	1.3	30.9	30.2	3.0	f
09-May	cloudless	37.3	1.0	40.4	40.7	1.9	f
13-May	o.c. 100%	30.3	0.3	locked	locked	1.2	r
16-May	cloudless	34.5	1.1	36.1	36.8	3.5	r
20-May	cloudless	31.6	1.1	33.7	33.4	3.0	b
23-May	cloudless	31.0	0.7	32.6	32.6	2.1	r
27-May	cloudless	32.6	1.2	33.2	33.5	4.1	b
30-May	o.c. 100%	29.9	0.6	31.8	31.4	2.1	r
03-Jun	cloudless	33.8	0.7	34.9	34.3	1.9	b
15-Jun	cloudless	29.2	1.1	30.2	29.9	3.2	b
17-Jun	cloudless	32.7	0.8	33.1	33.5	2.1	b
20-Jun	cloudless	29.9	1.5	30.6	30.3	4.5	r
27-Jun	cloudless	30.2	0.6	29.0	29.1	1.3	b
04-Jul	cloudless	29.7	0.9	29.5	29.0	1.7	f
11-Jul	cloudless	32.5	0.8	32.5	33.0	2.3	r
15-Jul	cloudless	30.9	0.7	31.4	31.5	2.2	b
18-Jul	o.c. 100%	28.1	1.5	28.1	27.4	4.3	r
22-Jul	o.c. 100%	28.5	0.6	27.1	26.5	1.9	l

Tanghin- Taambila B2 Venturi 15cm separation							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.5	37.7	locked	1.2	l
04-Mar	o.c. 25%	29.8	0.9	32.9	30.7	3.1	b
07-Mar	cloudless	33.3	0.6	33.8	34.3	1.6	l
11-Mar	o.c. 25%	33.8	0.7	35.3	locked	2.3	b
23-Mar	o.c. 50%	40.1	0.4	40.2	locked	0.7	b
05-Apr	o.c. 25%	33.9	1.3	33.3	locked	3.8	f
08-Apr	cloudless	33.7	0.9	33.4	32.9	2.6	r
11-Apr	cloudless	37.3	0.5	37.1	37.2	1.5	l
15-Apr	cloudless	35.9	0.7	34.8	34.8	2.3	r
18-Apr	cloudless	36.5	0.4	37.4	38.6	0.9	f
22-Apr	cloudless	37.1	1.2	36.0	36.4	2.8	f
26-Apr	cloudless	33.4	1.1	35.5	35.8	3.2	r
29-Apr	cloudless	35.6	1.3	36.1	36.7	4.2	r
03-May	o.c. 25%	30.7	0.7	31.2	31.0	2.1	r
06-May	o.c. 100%	30.3	0.5	30.4	30.2	1.2	f
09-May	cloudless	37.3	0.9	40.2	40.7	2.2	f
13-May	o.c. 100%	30.3	0.4	locked	locked	1.0	r
16-May	cloudless	34.5	0.7	36.7	36.8	2.2	r
20-May	cloudless	31.6	0.7	33.5	33.4	2.6	b
23-May	cloudless	31.0	1.1	32.5	32.6	3.9	r
27-May	cloudless	32.6	1.1	33.0	33.5	4.0	b
30-May	o.c. 100%	29.9	0.6	31.4	31.4	2.1	r
03-Jun	cloudless	33.8	0.6	35.1	34.3	1.8	b
15-Jun	cloudless	29.2	1.4	30.3	29.9	5.8	b
17-Jun	cloudless	32.7	1.2	33.2	33.5	4.8	b
20-Jun	cloudless	29.9	0.5	30.9	30.3	1.3	r
27-Jun	cloudless	30.2	0.6	29.0	29.1	1.7	b
04-Jul	cloudless	29.7	0.8	29.4	29.0	1.9	f
11-Jul	cloudless	32.5	0.9	33.3	33.0	3.0	r
15-Jul	cloudless	30.9	0.9	31.4	31.5	3.5	b
18-Jul	o.c. 100%	28.1	0.7	28.2	27.4	2.0	r
22-Jul	o.c. 100%	28.5	0.8	26.8	26.5	2.1	l

Tanghin- Taambila B3 Single Venturi							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.6	37.8	locked	1.4	l
04-Mar	o.c. 25%	29.8	0.7	31.8	30.7	1.6	b
07-Mar	cloudless	33.3	0.3	34.2	34.3	0.7	l
11-Mar	o.c. 25%	33.8	0.5	36.0	locked	0.9	b
23-Mar	o.c. 50%	40.1	0.7	39.6	locked	1.8	b
05-Apr	o.c. 25%	33.9	0.8	33.3	locked	1.8	f
08-Apr	cloudless	33.7	0.5	33.3	32.9	1.5	r
11-Apr	cloudless	37.3	1.8	37.7	37.2	4.8	l
15-Apr	cloudless	35.9	0.9	35.0	34.8	2.8	r
18-Apr	cloudless	36.5	0.6	38.5	38.6	1.2	f
22-Apr	cloudless	37.1	0.7	35.9	36.4	1.5	f
26-Apr	cloudless	33.4	1.4	35.7	35.8	4.0	r
29-Apr	cloudless	35.6	1.0	36.6	36.7	3.1	r
03-May	o.c. 25%	30.7	0.5	31.3	31.0	1.4	r
06-May	o.c. 100%	30.3	0.4	30.4	30.2	1.2	f
09-May	cloudless	37.3	1.0	39.9	40.7	2.4	f
13-May	o.c. 100%	30.3	0.4	locked	locked	1.2	r
16-May	cloudless	34.5	1.0	36.7	36.8	3.4	r
20-May	cloudless	31.6	0.5	33.6	33.4	1.8	b
23-May	cloudless	31.0	0.6	32.7	32.6	2.1	r
27-May	cloudless	32.6	1.0	32.4	33.5	3.4	b
30-May	o.c. 100%	29.9	0.4	31.6	31.4	1.3	r
03-Jun	cloudless	33.8	1.2	33.3	34.3	4.0	b
15-Jun	cloudless	29.2	1.5	29.9	29.9	5.5	b
17-Jun	cloudless	32.7	0.8	33.6	33.5	2.3	b
20-Jun	cloudless	29.9	0.4	31.0	30.3	1.1	r
27-Jun	cloudless	30.2	1.4	29.1	29.1	4.8	b
04-Jul	cloudless	29.7	0.3	29.4	29.0	0.5	f
11-Jul	cloudless	32.5	0.6	32.9	33.0	1.8	r
15-Jul	cloudless	30.9	0.9	31.4	31.5	2.8	b
18-Jul	o.c. 100%	28.1	0.7	27.8	27.4	2.0	r
22-Jul	o.c. 100%	28.5	0.8	26.9	26.5	2.9	l

Tanghin- Taambila B4 Venturi 10cm separation							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
28-Feb	cloudless	33.6	0.6	37.4	locked	1.6	l
04-Mar	o.c. 25%	29.8	0.7	31.3	30.7	2.2	b
07-Mar	cloudless	33.3	0.4	33.7	34.3	1.2	l
11-Mar	o.c. 25%	33.8	0.5	36.5	locked	1.5	b
23-Mar	o.c. 50%	40.1	0.5	39.3	locked	1.0	b
05-Apr	o.c. 25%	33.9	0.7	32.8	locked	1.8	f
08-Apr	cloudless	33.7	0.5	33.2	32.9	1.6	r
11-Apr	cloudless	37.3	0.6	36.5	37.2	1.6	l
15-Apr	cloudless	35.9	0.8	35.0	34.8	2.7	r
18-Apr	cloudless	36.5	0.2	38.5	38.6	0.2	f
22-Apr	cloudless	37.1	0.4	36.7	36.4	1.0	f
26-Apr	cloudless	33.4	1.0	35.9	35.8	3.5	r
29-Apr	cloudless	35.6	0.7	37.0	36.7	2.6	r
03-May	o.c. 25%	30.7	0.6	31.2	31.0	2.0	r
06-May	o.c. 100%	30.3	0.5	30.6	30.2	1.2	f
09-May	cloudless	37.3	0.8	39.0	30.2	2.1	f
13-May	o.c. 100%	30.3	0.3	locked	locked	1.1	r
16-May	cloudless	34.5	0.6	36.2	36.8	2.8	r
20-May	cloudless	31.6	0.6	33.4	33.4	1.8	b
23-May	cloudless	31.0	0.7	33.0	32.6	2.0	r
27-May	cloudless	32.6	1.1	32.8	33.5	4.5	b
30-May	o.c. 100%	29.9	1.3	31.5	31.4	4.2	r
03-Jun	cloudless	33.8	1.1	34.3	34.3	4.8	b
15-Jun	cloudless	29.2	1.3	30.2	29.9	5.8	b
17-Jun	cloudless	32.7	1.2	33.0	33.5	5.5	b
20-Jun	cloudless	29.9	0.6	31.2	30.3	1.7	r
27-Jun	cloudless	30.2	1.3	29.1	29.1	5.9	b
04-Jul	cloudless	29.7	0.2	29.6	29.0	0.1	f
11-Jul	cloudless	32.5	0.7	32.9	33.0	2.2	r
15-Jul	cloudless	30.9	0.7	31.4	31.5	2.4	b
18-Jul	o.c. 100%	28.1	0.7	28.0	27.4	2.0	r
22-Jul	o.c. 100%	28.5	0.7	26.9	26.5	2.4	l

Tanghin- Taambila B5 Control							
Date	**Ambient Conditions**	**Ambient Temp.**	**Ventpipe Velocity m/s**	**Ventpipe Temp. °C**	**Latrine Temp. °C**	**Wind Velocity m/s**	**Wind Direction**
28-Feb	cloudless	33.6	0.2	38.1	locked	1.2	l
04-Mar	o.c. 25%	29.8	0.5	30.4	30.7	2.3	b
07-Mar	cloudless	33.3	0.1	33.4	34.3	0.9	l
11-Mar	o.c. 25%	33.8	0.3	36.7	locked	1.1	b
23-Mar	o.c. 50%	40.1	0.4	39.8	locked	1.3	b
05-Apr	o.c. 25%	33.9	1.1	33.1	locked	4.0	f
08-Apr	cloudless	33.7	0.4	33.1	32.9	1.9	r
11-Apr	cloudless	37.3	0.2	37.5	37.2	1.1	l
15-Apr	cloudless	35.9	0.4	35.4	34.8	2.3	r
18-Apr	cloudless	36.5	0.7	38.9	38.6	2.0	f
22-Apr	cloudless	37.1	0.5	36.9	36.4	1.4	f
26-Apr	cloudless	33.4	0.6	35.9	35.8	2.8	r
29-Apr	cloudless	35.6	0.5	37.0	36.7	2.3	r
03-May	o.c. 25%	30.7	0.8	31.4	31.0	3.6	r
06-May	o.c. 100%	30.3	0.4	30.6	30.2	1.2	f
09-May	cloudless	37.3	1.0	38.2	30.2	2.8	f
13-May	o.c. 100%	30.3	0.3		30.3	1.7	r
16-May	cloudless	34.5	0.4	36.6	36.8	2.4	r
20-May	cloudless	31.6	0.4	33.0	33.4	1.5	b
23-May	cloudless	31.0	0.3	33.3	32.6	1.6	r
27-May	cloudless	32.6	0.6	32.1	33.5	2.6	b
30-May	o.c. 100%	29.9	0.2	31.6	31.4	1.6	r
03-Jun	cloudless	33.8	0.6	34.1	34.3	2.5	b
15-Jun	cloudless	29.2	0.9	30.2	29.9	4.0	b
17-Jun	cloudless	32.7	1.0	33.2	33.5	4.9	b
20-Jun	cloudless	29.9	1.3	31.2	30.3	4.7	r
27-Jun	cloudless	30.2	0.5	29.0	29.1	1.9	b
04-Jul	cloudless	29.7	0.1	29.7	29.0	0.1	f
11-Jul	cloudless	32.5	0.9	33.6	33.0	4.2	r
15-Jul	cloudless	30.9	0.5	31.4	31.5	1.8	b
18-Jul	o.c. 100%	28.1	0.5	28.0	27.4	2.1	r
22-Jul	o.c. 100%	28.5	0.3	27.0	26.5	1.8	l

Ecole Dagnoin Bloc A

Dagnoin A1 Slotted without Top							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	1.5	29.5	30.7	3.2	b
21-Feb	cloudless	28.9	0.4	30.0	30.9	1.2	b
28-Feb	cloudless	27.1	0.5	30.1	32.8	1.3	b
04-Mar	o.c. 25%	28.4	1.2	27.8	27.4	2.4	b
07-Mar	cloudless	29.0	0.4	29.7	30.8	1.2	r
11-Mar	o.c. 25%	29.8	0.8	31.8	32.3	1.8	b
14-Mar	o.c. 50%	29.9	1.2	29.8	2.2	2.2	l
18-Mar	cloudless	29.9	2.2	31.0	locked	3.2	f
23-Mar	cloudless	36.3	0.3	31.3	locked	0.9	l
05-Apr	o.c. 25%	29.0	1.9	29.2	locked	3.8	b
11-Apr	cloudless	31.2	1.1	31.3	32.7	2.1	r
18-Apr	cloudless	33.1	1.8	33.4	34.4	2.7	f
22-Apr	cloudless	31.7	2.4	31.7	32.0	3.5	r
26-Apr	cloudless	34.7	1.6	35.5	35.9	2.6	r
29-Apr	cloudless	32.1	2.9	32.6	34.1	4.0	f
03-May	o.c. 25%	29.9	1.4	30.3	29.9	3.1	b
06-May	cloudless	31.9	0.5	33.0	33.8	1.0	r
09-May	cloudless	33.1	3.1	33.0	34.9	4.2	f
13-May	o.c. 100%	29.5	1.1	29.6	29.0	2.3	f
16-May	cloudless	31.4	0.9	32.3	33.5	1.9	r
20-May	cloudless	33.4	0.1	34.4	36.6	0.4	l
23-May	cloudless	32.5	1.8	33.4	34.2	2.9	l
27-May	cloudless	29.5	2.0	30.8	31.1	3.0	r
30-May	o.c. 100%	29.2	0.5	29.9	29.4	1.1	r
03-Jun	cloudless	28.7	0.8	30.0	30.6	1.7	r
15-Jun	cloudless	35.1	0.2	33.7	35.0	1.4	f
17-Jun	cloudless	30.3	0.2	30.6	locked	1.5	f
20-Jun	cloudless	32.4	1.3	32.7	locked	2.6	b
27-Jun	o.c. 100%	28.8	0.4	29.4	locked	1.0	r
04-Jul	o.c. 25%	29.1	1.0	28.7	locked	1.9	r
11-Jul	cloudless	28.5	0.1	29.8	31.5	1.1	f
15-Jul	cloudless	27.2	0.5	28.4	locked	1.7	f
18-Jul	o.c. 25%	29.0	1.2	29.3	29.1	2.3	l
22-Jul	cloudless	27.0	0.5	27.1	locked	1.4	r

Dagnoin A2 Slotted with Top							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	1.7	29.6	30.7	3.5	b
21-Feb	cloudless	28.9	0.4	30.5	30.9	1.0	b
28-Feb	cloudless	27.1	0.6	33.3	33.1	1.5	b
04-Mar	o.c. 25%	28.4	1.3	27.7	27.4	2.3	b
07-Mar	cloudless	29.0	0.4	29.6	30.8	1.4	r
11-Mar	o.c. 25%	29.8	0.3	32.7	32.3	0.8	b
14-Mar	o.c. 50%	29.9	1.6	30.0	locked	2.6	l
18-Mar	cloudless	29.9	0.7	32.7	locked	1.7	f
23-Mar	cloudless	36.3	0.5	35.0	locked	1.2	l
05-Apr	o.c. 25%	29.0	1.8	29.3	29.3	3.7	b
11-Apr	cloudless	31.2	2.2	31.9	32.7	3.5	r
18-Apr	cloudless	33.1	1.5	34.0	34.4	2.5	f
22-Apr	cloudless	31.7	1.3	31.9	32.0	2.2	r
26-Apr	cloudless	34.7	1.4	35.5	35.9	2.1	r
29-Apr	cloudless	32.1	2.3	33.2	34.1	3.2	f
03-May	o.c. 25%	29.9	1.4	30.5	29.9	2.6	b
06-May	cloudless	31.9	1.5	33.4	33.8	2.6	r
09-May	cloudless	33.1	1.9	33.5	34.9	2.8	f
13-May	o.c. 100%	29.5	0.9	29.7	29.0	2.0	f
16-May	cloudless	31.4	1.3	32.6	33.5	2.2	r
20-May	cloudless	33.4	0.6	35.1	36.6	1.5	l
23-May	cloudless	32.5	0.2	33.6	34.2	0.8	l
27-May	cloudless	29.5	1.4	30.7	31.1	2.3	r
30-May	o.c. 100%	29.2	0.8	29.8	29.4	1.6	r
03-Jun	cloudless	28.7	0.4	30.2	30.6	1.3	r
15-Jun	cloudless	35.1	0.1	34.7	35.0	0.9	f
17-Jun	cloudless	30.3	0.2	31.2	locked	1.1	f
20-Jun	cloudless	32.4	0.9	33.3	locked	1.8	b
27-Jun	o.c. 100%	28.8	0.3	29.9	locked	1.0	r
04-Jul	o.c. 25%	29.1	1.1	29.1	locked	1.8	r
11-Jul	cloudless	28.5	0.4	31.0	31.5	1.5	f
15-Jul	cloudless	27.2	1.3	29.7	locked	2.3	f
18-Jul	o.c. 25%	29.0	1.8	29.4	29.1	3.1	l
22-Jul	cloudless	27.0	1.4	27.1	locked	2.4	r

Dagnoin A3 Control							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	1.2	29.4	30.6	3.2	b
21-Feb	cloudless	28.9	0.6	30.2	30.9	1.0	b
28-Feb	cloudless	27.1	0.5	33.8	33.4	0.9	b
04-Mar	o.c. 25%	28.4	1.0	27.5	27.4	2.7	b
07-Mar	cloudless	29.0	0.3	30.9	30.8	1.0	r
11-Mar	o.c. 25%	29.8	0.7	32.7	32.3	1.5	b
14-Mar	o.c. 50%	29.9	0.5	30.3	locked	1.4	l
18-Mar	cloudless	29.9	1.5	32.8	locked	3.1	f
23-Mar	cloudless	36.3	0.7	35.7	locked	1.9	l
05-Apr	o.c. 25%	29.0	1.1	29.6	29.3	2.8	b
11-Apr	cloudless	31.2	0.8	32.3	32.7	2.3	r
18-Apr	cloudless	33.1	0.6	34.5	34.4	2.0	f
22-Apr	cloudless	31.7	0.7	32.4	32.0	1.8	r
26-Apr	cloudless	34.7	0.1	35.5	35.9	0.3	r
29-Apr	cloudless	32.1	0.9	33.5	34.1	2.1	f
03-May	o.c. 25%	29.9	0.7	30.7	29.9	1.4	b
06-May	cloudless	31.9	0.6	33.9	33.8	1.6	r
09-May	cloudless	33.1	1.7	33.7	34.9	3.5	f
13-May	o.c. 100%	29.5	1.1	29.6	29.0	2.4	f
16-May	cloudless	31.4	0.7	33.0	33.5	2.0	r
20-May	cloudless	33.4	0.6	35.1	36.6	1.7	l
23-May	cloudless	32.5	1.4	34.0	34.2	2.9	l
27-May	cloudless	29.5	0.6	30.8	31.1	1.8	r
30-May	o.c. 100%	29.2	0.5	29.8	29.4	1.5	r
03-Jun	cloudless	28.7	0.8	30.4	30.6	2.6	r
15-Jun	cloudless	35.1	1.3	34.1	35.0	2.7	f
17-Jun	cloudless	30.3	0.5	31.4	locked	1.5	f
20-Jun	cloudless	32.4	0.8	33.3	locked	1.8	b
27-Jun	o.c. 100%	28.8	0.4	30.1	locked	1.1	r
04-Jul	o.c. 25%	29.1	0.4	29.1	locked	1.3	r
11-Jul	cloudless	28.5	1.1	31.2	31.5	2.3	f
15-Jul	cloudless	27.2	0.6	30.0	locked	1.8	f
18-Jul	o.c. 25%	29.0	1.6	29.6	29.1	3.3	l
22-Jul	cloudless	27.0	1.1	27.1	locked	2.7	r

Dagnoin A4 Venturi 10cm Separation							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	1.4	29.4	30.7	3.3	b
21-Feb	cloudless	28.9	0.8	30.2	30.9	1.0	b
28-Feb	cloudless	27.1	0.6	33.3	33.8	0.7	b
04-Mar	o.c. 25%	28.4	1.1	27.9	27.4	2.2	b
07-Mar	cloudless	29.0	0.3	31.3	30.8	0.6	r
11-Mar	o.c. 25%	29.8	1.0	33.2	32.3	2.0	b
14-Mar	o.c. 50%	29.9	0.7	30.1	locked	1.2	l
18-Mar	cloudless	29.9	2.0	31.1	locked	3.3	f
23-Mar	cloudless	36.3	0.8	35.7	locked	1.5	l
05-Apr	o.c. 25%	29.0	1.3	29.5	29.3	2.9	b
11-Apr	cloudless	31.2	0.4	32.6	32.7	0.8	r
18-Apr	cloudless	33.1	1.3	34.8	34.8	2.2	f
22-Apr	cloudless	31.7	0.6	32.5	32.0	1.3	r
26-Apr	cloudless	34.7	0.2	35.6	35.9	0.3	r
29-Apr	cloudless	32.1	1.1	33.7	34.1	2.1	f
03-May	o.c. 25%	29.9	1.0	30.9	29.9	2.2	b
06-May	cloudless	31.9	0.8	34.2	33.8	1.6	r
09-May	cloudless	33.1	1.8	34.2	34.9	3.0	f
13-May	o.c. 100%	29.5	0.7	29.7	29.0	1.5	f
16-May	cloudless	31.4	0.6	33.0	33.5	1.1	r
20-May	cloudless	33.4	0.9	35.2	36.6	1.8	l
23-May	cloudless	32.5	1.7	33.8	34.2	3.5	l
27-May	cloudless	29.5	1.1	30.9	31.1	2.1	r
30-May	o.c. 100%	29.2	0.7	29.7	29.4	1.3	r
03-Jun	cloudless	28.7	0.4	30.4	30.6	0.7	r
15-Jun	cloudless	35.1	1.5	34.1	35.0	2.6	f
17-Jun	cloudless	30.3	2.2	31.4	locked	4.0	f
20-Jun	cloudless	32.4	0.9	33.2	locked	1.6	b
27-Jun	o.c. 100%	28.8	0.4	30.0	locked	0.9	r
04-Jul	o.c. 25%	29.1	1.5	31.1	locked	2.8	r
11-Jul	cloudless	28.5	0.9	31.4	31.5	1.9	f
15-Jul	cloudless	27.2	1.7	30.1	locked	2.8	f
18-Jul	o.c. 25%	29.0	0.6	30.1	29.1	1.1	l
22-Jul	cloudless	27.0	1.3	27.1	locked	2.4	r

Dagnoin A5 Single Venturi							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	1.7	28.8	30.8	3.3	b
21-Feb	cloudless	28.9	1.8	30.2	30.9	3.5	b
28-Feb	cloudless	27.1	0.9	33.6	34.0	1.3	b
04-Mar	o.c. 25%	28.4	1.3	27.9	27.4	2.3	b
07-Mar	cloudless	29.0	1.1	30.7	30.8	1.6	r
11-Mar	o.c. 25%	29.8	1.2	32.6	32.3	2.2	b
14-Mar	o.c. 50%	29.9	1.2	30.2	locked	1.9	l
18-Mar	cloudless	29.9	2.4	35.5	locked	3.4	f
23-Mar	cloudless	36.3	0.2	35.5	locked	0.5	l
05-Apr	o.c. 25%	29.0	1.6	29.4	29.3	3.2	b
11-Apr	cloudless	31.2	0.3	33.0	32.7	0.6	r
18-Apr	cloudless	33.1	1.2	34.6	34.4	2.0	f
22-Apr	cloudless	31.7	1.3	32.6	32.0	2.1	r
26-Apr	cloudless	34.7	0.8	35.8	35.9	1.3	r
29-Apr	cloudless	32.1	0.7	34.5	34.1	1.3	f
03-May	o.c. 25%	29.9	0.7	30.7	29.9	0.6	b
06-May	cloudless	31.9	0.9	34.1	33.8	1.4	r
09-May	cloudless	33.1	0.9	34.6	34.9	1.6	f
13-May	o.c. 100%	29.5	0.8	29.4	29.0	1.4	f
16-May	cloudless	31.4	0.7	33.5	33.5	1.2	r
20-May	cloudless	33.4	1.0	35.8	36.6	1.8	l
23-May	cloudless	32.5	1.8	33.9	34.2	2.8	l
27-May	cloudless	29.5	1.9	30.7	31.1	3.4	r
30-May	o.c. 100%	29.2	1.0	29.5	29.4	1.6	r
03-Jun	cloudless	28.7	1.1	30.7	30.6	2.0	r
15-Jun	cloudless	35.1	2.8	34.1	35.0	4.0	f
17-Jun	cloudless	30.3	1.9	31.5	locked	2.8	f
20-Jun	cloudless	32.4	1.0	34.1	locked	1.5	b
27-Jun	o.c. 100%	28.8	1.0	30.4	locked	1.4	r
04-Jul	o.c. 25%	29.1	1.6	30.9	locked	2.6	r
11-Jul	cloudless	28.5	1.7	31.1	31.5	2.5	f
15-Jul	cloudless	27.2	1.4	30.1	locked	2.2	f
18-Jul	o.c. 25%	29.0	1.4	30.2	29.1	2.1	l
22-Jul	cloudless	27.0	0.6	26.8	locked	1.0	r

Ecole Dagnoin Bloc B

Dagnoin B1 Divergent 25 cm							
Date	**Ambient Conditions**	**Ambient Temp.**	**Ventpipe Velocity m/s**	**Ventpipe Temp. °C**	**Latrine Temp. °C**	**Wind Velocity m/s**	**Wind Direction**
08-Feb	cloudless	32.2	1.8	28.3	locked	3.3	f
21-Feb	cloudless	28.9	1.5	28.1	29.7	2.8	f
28-Feb	cloudless	27.1	1.5	27.7	28.7	2.1	f
04-Mar	o.c. 25%	28.4	1.5	28.2	27.3	2.4	f
07-Mar	cloudless	29.0	0.8	28.6	29.2	3.3	l
11-Mar	o.c. 25%	29.8	1.4	31.8	32.0	2.0	f
14-Mar	o.c. 50%	29.9	1.3	29.8	29.3	5	r
18-Mar	cloudless	29.9	1.9	31.5	locked	4.5	b
23-Mar	cloudless	36.3	0.5	34.6	36.3	1.5	r
05-Apr	o.c. 25%	29.0	2.2	29.6	locked	4.0	f
11-Apr	cloudless	34.7	0.7	34.5	33.2	3.0	l
18-Apr	cloudless	33.1	1.1	34.9	locked	2.5	b
22-Apr	cloudless	31.7	0.5	33.1	31.8	2.5	l
26-Apr	cloudless	34.7	0.6	35.8	35.4	2.7	l
29-Apr	cloudless	32.1	1.3	35.0	34.1	3.6	b
03-May	o.c. 25%	29.9	1.3	31.6	30.8	2.1	f
06-May	cloudless	31.9	0.4	36.1	35.4	1.1	l
09-May	cloudless	33.1	1.1	35.4	35.9	2.2	b
13-May	o.c. 100%	29.5	1.1	29.8	29.3	2.1	b
16-May	cloudless	31.4	0.9	35.2	34.3	3.3	l
20-May	cloudless	33.4	0.3	36.2	35.4	0.9	r
23-May	cloudless	32.5	0.4	35.0	34.4	1.3	r
27-May	cloudless	29.5	1.8	31.4	30.7	7.2	l
30-May	o.c. 100%	29.2	1.0	30.1	29.2	3.4	l
03-Jun	cloudless	28.7	0.6	30.7	30.2	2.3	l
15-Jun	cloudless	35.1	2.0	34.0	33.6	5.5	b
17-Jun	cloudless	30.3	2.1	31.4	31.0	5.8	b
20-Jun	cloudless	32.4	0.8	32.9	32.9	1.3	f
27-Jun	o.c. 100%	28.8	0.5	31.3	31.2	1.8	l
04-Jul	o.c. 25%	29.1	1.2	38.7	33.4	1.6	f
11-Jul	cloudless	28.5	1.2	30.9	29.7	2.7	b
15-Jul	cloudless	27.2	1.0	29.1	28.9	2.0	b
18-Jul	o.c. 25%	29.0	0.4	30.0	29.7	1.9	r
22-Jul	cloudless	27.0	0.5	27.4	27.0	2.2	l

Dagnoin B2 Divergent 35 cm							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	2	27.6	locked	3.8	f
21-Feb	cloudless	28.9	1	28.3	29.7	1.3	f
28-Feb	cloudless	27.1	1.6	27.8	28.9	2.2	f
04-Mar	o.c. 25%	28.4	1.7	27.9	27.3	3.1	f
07-Mar	cloudless	29.0	1.4	28.3	29.2	5.0	l
11-Mar	o.c. 25%	29.8	1.7	31.4	32.0	2.6	f
14-Mar	o.c. 50%	29.9	1.6	29.7	29.3	5.8	r
18-Mar	cloudless	29.9	1.5	31.1	locked	4.1	b
23-Mar	cloudless	36.3	1.0	34.2	36.3	4.1	r
05-Apr	o.c. 25%	29.0	2.1	29.5	locked	4.2	f
11-Apr	cloudless	34.7	0.7	33.1	33.2	3.1	l
18-Apr	cloudless	33.1	1.0	34.2	locked	1.8	b
22-Apr	cloudless	31.7	0.9	32.1	31.8	3.2	l
26-Apr	cloudless	34.7	0.6	35.3	35.4	2.2	l
29-Apr	cloudless	32.1	2.7	34.9	34.1	6.8	b
03-May	o.c. 25%	29.9	1.4	30.3	30.8	2.0	f
06-May	cloudless	31.9	0.4	35.2	35.4	1.3	l
09-May	cloudless	33.1	0.9	35.4	35.9	2.2	b
13-May	o.c. 100%	29.5	1.0	29.3	29.3	2.6	b
16-May	cloudless	31.4	1.5	34.1	34.3	5.3	l
20-May	cloudless	33.4	0.5	35.1	35.4	1.8	r
23-May	cloudless	32.5	0.8	34.1	34.4	3.2	r
27-May	cloudless	29.5	1.8	30.6	30.7	6.9	l
30-May	o.c. 100%	29.2	1.0	29.6	29.2	3.6	l
03-Jun	cloudless	28.7	0.5	30.2	30.2	1.4	l
15-Jun	cloudless	35.1	2.0	33.9	33.6	5.4	b
17-Jun	cloudless	30.3	1.2	30.9	31.0	3.1	b
20-Jun	cloudless	32.4	0.7	31.8	32.9	0.7	f
27-Jun	o.c. 100%	28.8	0.3	31.0	31.2	1.1	l
04-Jul	o.c. 25%	29.1	2.1	28.9	38.4	4.1	f
11-Jul	cloudless	28.5	1.0	30.7	29.7	2.1	b
15-Jul	cloudless	27.2	1.3	29.2	28.9	2.8	b
18-Jul	o.c. 25%	29.0	0.6	30.1	29.7	2.4	r
22-Jul	cloudless	27.0	1.5	26.9	27.0	5.4	l

Dagnoin B3 Slotted without Top

Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	2.6	27.7	locked	3.4	f
21-Feb	cloudless	28.9	0.7	28.1	29.7	1.3	f
28-Feb	cloudless	27.1	1.3	27.7	29.4	1.6	f
04-Mar	o.c. 25%	28.4	0.6	27.8	27.3	1.1	f
07-Mar	cloudless	29.0	1.9	28.8	29.2	5.0	l
11-Mar	o.c. 25%	29.8	1.8	31.6	32.0	2.0	f
14-Mar	o.c. 50%	29.9	1.8	29.8	29.3	4.8	r
18-Mar	cloudless	29.9	1.4	31.8	locked	2.8	b
23-Mar	cloudless	36.3	0.5	33.6	36.3	2.5	r
05-Apr	o.c. 25%	29.0	3.0	29.4	locked	4.0	f
11-Apr	cloudless	34.7	2.4	33.0	33.2	5.8	l
18-Apr	cloudless	33.1	0.7	33.9	locked	1.8	b
22-Apr	cloudless	31.7	1.1	32.3	31.8	3.4	l
26-Apr	cloudless	34.7	0.7	34.7	35.4	2.6	l
29-Apr	cloudless	32.1	2.8	33.8	34.1	4.9	b
03-May	o.c. 25%	29.9	1.5	30.2	30.8	1.8	f
06-May	cloudless	31.9	0.5	34.9	35.4	1.5	l
09-May	cloudless	33.1	1.6	35.3	35.9	3.2	b
13-May	o.c. 100%	29.5	0.8	29.4	29.3	2.0	b
16-May	cloudless	31.4	1.5	33.8	34.3	4.0	l
20-May	cloudless	33.4	0.6	35.0	35.4	2.1	r
23-May	cloudless	32.5	0.3	34.2	34.4	1.2	r
27-May	cloudless	29.5	2.5	30.5	30.7	6.2	l
30-May	o.c. 100%	29.2	1.5	29.5	29.2	3.9	l
03-Jun	cloudless	28.7	0.5	30.2	30.2	1.8	l
15-Jun	cloudless	35.1	2.3	34.1	33.6	4.2	b
17-Jun	cloudless	30.3	0.9	30.4	31.0	2.4	b
20-Jun	cloudless	32.4	0.1	31.3	32.9	0.7	f
27-Jun	o.c. 100%	28.8	0.3	31.2	31.2	1.0	l
04-Jul	o.c. 25%	29.1	1.8	27.9	38.4	2.1	f
11-Jul	cloudless	28.5	1.9	29.4	29.7	3.6	b
15-Jul	cloudless	27.2	1.0	29.4	28.9	2.5	b
18-Jul	o.c. 25%	29.0	0.4	29.7	29.7	2.0	r
22-Jul	cloudless	27.0	1.4	27.1	27.0	3.6	l

Dagnoin B4 Slotted with Top							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	2.8	27.7	locked	4.1	f
21-Feb	cloudless	28.9	0.6	28.2	29.7	1.3	f
28-Feb	cloudless	27.1	0.5	28.6	29.4	1.1	f
04-Mar	o.c. 25%	28.4	2.6	27.3	27.3	3.5	f
07-Mar	cloudless	29.0	2.2	28.9	29.2	5.4	l
11-Mar	o.c. 25%	29.8	2.3	31.5	32.0	2.8	f
14-Mar	o.c. 50%	29.9	2.5	29.4	29.3	6.8	r
18-Mar	cloudless	29.9	2.2	31.4	locked	4.1	b
23-Mar	cloudless	36.3	0.4	34.1	36.3	1.8	r
05-Apr	o.c. 25%	29.0	1.8	29.4	locked	2.5	f
11-Apr	cloudless	34.7	0.3	32.7	33.2	1.7	l
18-Apr	cloudless	33.1	1.9	33.6	locked	3.5	b
22-Apr	cloudless	31.7	0.7	32.0	31.8	2.1	l
26-Apr	cloudless	34.7	1.0	34.7	35.4	2.7	l
29-Apr	cloudless	32.1	0.8	33.9	34.1	1.8	b
03-May	o.c. 25%	29.9	1.8	30.2	30.8	2.4	f
06-May	cloudless	31.9	0.2	34.6	35.4	1.2	l
09-May	cloudless	33.1	0.8	35.2	35.9	1.8	b
13-May	o.c. 100%	29.5	1.2	29.5	29.3	2.4	b
16-May	cloudless	31.4	2.0	33.5	29.3	5.0	l
20-May	cloudless	33.4	1.2	35.0	35.4	2.9	r
23-May	cloudless	32.5	1.3	34.0	34.4	3.4	r
27-May	cloudless	29.5	2.7	30.5	30.7	7.0	l
30-May	o.c. 100%	29.2	0.7	29.5	29.2	2.2	l
03-Jun	cloudless	28.7	0.2	30.0	30.2	1.4	l
15-Jun	cloudless	35.1	2.9	32.9	33.6	5.4	b
17-Jun	cloudless	30.3	2.1	30.6	31.0	4.0	b
20-Jun	cloudless	32.4	0.2	31.1	32.9	0.9	f
27-Jun	o.c. 100%	28.8	0.2	31.0	31.2	1.6	l
04-Jul	o.c. 25%	29.1	0.1	27.9	38.4	0.7	f
11-Jul	cloudless	28.5	0.7	29.6	29.7	1.4	b
15-Jul	cloudless	27.2	1.5	29.4	28.9	2.7	b
18-Jul	o.c. 25%	29.0	0.1	29.2	29.7	1.1	r
22-Jul	cloudless	27.0	1.8	26.9	27.0	4.2	l

Dagnoin B5 Control							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
08-Feb	cloudless	32.2	1.8	27.9	locked	3.4	f
21-Feb	cloudless	28.9	1.6	28.1	29.7	2.5	f
28-Feb	cloudless	27.1	0.8	29.0	29.7	1.0	f
04-Mar	o.c. 25%	28.4	1.5	27.6	27.3	2.2	f
07-Mar	cloudless	29.0	0.9	28.5	29.2	3.5	l
11-Mar	o.c. 25%	29.8	2.0	31.1	32.0	4.0	f
14-Mar	o.c. 50%	29.9	1.5	29.6	29.3	5.5	r
18-Mar	cloudless	29.9	2.0	31.4	locked	5.5	b
23-Mar	cloudless	36.3	0.4	33.9	36.3	1.5	r
05-Apr	o.c. 25%	29.0	1.7	29.3	locked	3.2	f
11-Apr	cloudless	34.7	0.3	32.6	33.2	1.4	l
18-Apr	cloudless	33.1	1.2	33.5	locked	3.0	b
22-Apr	cloudless	31.7	0.8	31.8	31.8	3.2	l
26-Apr	cloudless	34.7	0.5	34.8	35.4	2.1	l
29-Apr	cloudless	32.1	1.0	33.4	34.1	1.8	b
03-May	o.c. 25%	29.9	1.7	30.2	30.8	3.0	f
06-May	cloudless	31.9	0.3	34.4	35.4	1.3	l
09-May	cloudless	33.1	1.0	35.0	35.9	2.2	b
13-May	o.c. 100%	29.5	1.1	29.3	29.3	2.6	b
16-May	cloudless	31.4	1.0	33.6	29.3	4.2	l
20-May	cloudless	33.4	0.5	35.0	35.4	2.2	r
23-May	cloudless	32.5	0.7	34.0	34.4	3.4	r
27-May	cloudless	29.5	1.8	30.3	30.7	6.8	l
30-May	o.c. 100%	29.2	0.5	29.5	29.2	2.2	l
03-Jun	cloudless	28.7	0.5	30.0	30.2	1.9	l
15-Jun	cloudless	35.1	2.1	32.8	33.6	5.6	b
17-Jun	cloudless	30.3	1.8	30.2	31.0	4.5	b
20-Jun	cloudless	32.4	0.3	31.3	32.9	0.3	f
27-Jun	o.c. 100%	28.8	1.0	30.8	31.2	3.7	l
04-Jul	o.c. 25%	29.1	0.9	27.9	38.4	1.4	f
11-Jul	cloudless	28.5	1.3	28.6	29.7	3.2	b
15-Jul	cloudless	27.2	1.6	29.3	28.9	4.2	b
18-Jul	o.c. 25%	29.0	0.6	29.4	29.7	2.8	r
22-Jul	cloudless	27.0	0.5	26.9	27.0	2.6	l

Antenne National

Slotted without Top							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
Apr 20	o.c. 25%	34.1	1.2	34.6	34.6	4.8	b
Apr 27	o.c. 25%	33.3	0.8	33.5	33.5	3.0	b
Feb 24	cloudless	30.5	0.2	33.2	33.9	1.4	b
Jun 15	cloudless	37.1	1.3	35.1	36.9	5.1	b
Jun 15	cloudless	37.1	1.4	35.1	36.9	5.8	b
Jun 22	cloudless	38.3	0.7	36.5	37.0	2.7	b
Jun 22	cloudless	38.3	0.2	36.5	37.0	1.8	b
Jun 29	cloudless	38.6	1.0	36.5	36.7	4.0	b
Jun 29	cloudless	38.6	0.9	36.5	36.7	3.4	b
Mar 23	cloudless	39.5	0.1	41.1	41.0	0.7	b
May 04	o.c. 25%	33.3	1.0	33.2	33.2	4.1	b
May 11	o.c. 100%	27.8	1.7	28.2	27.2	6.6	b
May 18	cloudless	36.6	1.6	36.2	36.5	6.4	b
Apr 06	cloudless	29.9	0.8	30.8	30.1	1.8	f
Mar 02	cloudless	30.8	0.5	32.3	32.6	0.7	f
Mar 09	o.c. 100%	30.0	0.6	31.3	30.9	0.7	f
Jun 03	cloudless	33.3	0.4	33.0	33.1	2.1	l
Mar 16	o.c. 100%	29.3	0.2	30.0	29.6	0.5	l
May 25	cloudless	37.8	0.7	37.4	37.8	4.1	l
Apr 13	cloudless	35.3	0.7	35.3	35.2	2.8	r

Control							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
Jun 29	cloudless	38.6	0.4	36.5	36.7	2.1	b
Jun 29	cloudless	38.6	0.7	36.5	36.7	3.6	b
Jul 06	cloudless	30.5	0.8	30.0	30.1	4.7	b
Jul 06	cloudless	30.5	1.0	30.0	30.1	6.2	b
Jul 06	cloudless	30.5	0.8	30.0	30.1	4.9	b
Jul 13	o.c. 100%	24.7	0.8	25.4	24.7	4.2	b
Jul 13	o.c. 100%	24.7	1.0	25.4	24.7	5.5	b
Jul 13	o.c. 100%	24.7	0.6	25.4	24.7	2.8	b
Jul 20	cloudless	34.8	0.2	33.5	33.5	1.5	b
Jul 20	cloudless	34.8	0.4	33.5	33.5	1.9	b
Jul 20	cloudless	34.8	0.1	33.5	33.5	1.3	b
Jul 27	o.c. rain	28.3	0.5	29.6	28.4	2.3	b
Jul 27	o.c. rain	28.3	0.3	29.6	28.4	1.7	b
Jul 27	o.c. rain	28.3	0.3	29.6	28.4	1.9	b
Aug 01	o.c. 100%	28	0.8	28.3	28.0	4.8	b
Aug 01	o.c. 100%	28	0.9	28.3	28.0	5.2	b
Aug 01	o.c. 100%	28	0.5	28.3	28.0	2.8	b
Aug 12	o.c. 100%	28.5	0.3	29.6	28.4	2.0	b
Aug 12	o.c. 100%	28.5	0.5	29.6	28.4	2.4	b
Aug 12	o.c. 100%	28.5	0.4	29.6	28.4	2.1	b

Cite AN II

Venturi 10 cm Separation							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
24-Feb	cloudless	35.5	0.5	34.2	35.4	1.1	r
02-Mar	cloudless	33.1	1.0	32.0	32.4	1.5	r
09-Mar	o.c. 100%	32.8	0.5	31.8	32.5	0.8	l
16-Mar	o.c. 100%	31.0	1.3	30.3	31.1	2.1	l
23-Mar	cloudless	38.7	0.1	38.3	38.3	0.3	l
06-Apr	cloudless	32.2	0.6	31.7	31.6	1.0	r
13-Apr	cloudless	37.1	1.0	36.3	36.1	1.6	r
20-Apr	o.c. 25%	35.3	1.4	34.9	34.9	2.4	r
27-Apr	o.c. 25%	35.0	1.1	34.2	34.4	2.2	r
04-May	o.c. 25%	33.7	0.3	33.4	33.5	0.4	l
11-May	o.c. 100%	27.6	1.3	28.1	27.8	2.3	r
18-May	cloudless	37.7	0.7	36.8	37.0	1.0	r
25-May	cloudless	33.5	1.2	33.3	33.4	2.0	l
15-Jun	cloudless	30.3	1.2	30.0	30.2	2.1	r
	cloudless	30.3	1.0	30.0	30.2	1.6	r
22-Jun	cloudless	35.6	1.1	35.6	34.9	1.8	r
	cloudless	35.6	0.8	35.6	34.9	1.3	r
29-Jun	cloudless	29.7	0.4	29.8	29.8	1.0	r
	cloudless	29.7	0.2	29.8	29.8	0.6	r

Control							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
29-Jun	cloudless	29.7	1.1	29.8	29.8	2.2	r
	cloudless	29.7	0.4	29.8	29.8	0.8	r
06-Jul	cloudless	31.0	0.5	30.3	30.8	1.2	r
	cloudless	31.0	0.4	30.3	30.8	1.0	r
	cloudless	31.0	0.7	30.3	30.8	1.6	r
13-Jul	o.c. 100%	25.4	0.6	25.7	25.1	1.4	r
	o.c. 100%	25.4	0.9	25.7	25.1	2.0	r
20-Jul	cloudless	27.4	0.2	26.9	27.0	0.6	r
	cloudless	27.4	0.5	26.9	27.0	1.1	r
	cloudless	27.4	0.1	26.9	27.0	0.4	r
27-Jul	o.c. rain	28.4	0.7	29.5	28.4	1.5	r
	o.c. rain	28.4	0.8	29.5	28.4	1.8	r
	o.c. rain	28.4	1.0	29.5	28.4	2.1	r
01-Aug	o.c. rain	28.2	0.2	28.3	28.3	0.5	r
	o.c. rain	28.2	0.1	28.3	28.3	0.3	r
	o.c. rain	28.2	0.3	28.3	28.3	0.7	r
12-Aug	o.c. 100%	28.7	0.4	29.4	28.5	0.8	r
	o.c. 100%	28.7	0.4	29.4	28.5	1.1	r
	o.c. 100%	28.7	0.5	29.4	28.5	1.3	r

Chez Ernest

Divergent 25 cm							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
May 11	o.c. 100%	27.6	0.9	28.9	28.9	2.0	f
Aug 01	o.c. rain	28.9	0.6	29.9	29.0	1.6	f
Aug 01			0.3	29.9	29.0	0.9	f
May 18	cloudless	37.8	0.9	37.5	38.1	1.9	f
Jul 06	cloudless	31.7	0.4	31.6	31.7	1.2	f
Jul 06			0.7	31.6	31.7	1.9	f
May 25	cloudless	30.9	1.1	31.4	31.5	2.8	f
Aug 12			0.9	29.9	29.7	2.3	f
Mar 16	o.c. 100%	32.6	0.5	31.2	31.4	1.5	f
Feb 24	cloudless	32.5	0.6	30.8	32.7	1.5	f
Mar 02	cloudless	33.1	0.5	32.2	32.6	1.3	f
Aug 12	o.c. 100 %	29.4	1.0	29.9	29.7	2.5	f
Apr 13	cloudless	38.1	0.7	37.1	37.8	1.8	f
Mar 23	cloudless	37.9	0.4	36.8	37.6	1.1	f
Jul 13			0.6	26.5	26.4	1.5	l
Jul 20	cloudless	28.9	0.6	28.7	28.4	1.4	l
Jul 27	o.c. rain	28.6	1.0	29.7	28.7	2.1	l
Jul 27			1.2	29.7	28.7	2.4	l
Jul 20			1.0	28.7	28.4	2.3	l
Jul 20			0.5	28.7	28.4	1.2	l
Jun 22	cloudless	32.3	0.2	32.0	32.2	0.5	l
Jun 15	cloudless	32.1	0.2	32.2	32.4	0.6	l
Jun 29	cloudless	28.7	0.4	29.2	29.1	1.3	l
Jul 13			0.9	26.5	26.4	2.2	l
Jul 13	o.c. 100%	26.4	0.8	26.5	26.4	1.8	l
Apr 06	cloudless	33.1	1.9	32.1	32.6	3.5	r
Mar 09	o.c. 100%	33.6	1.1	31.8	33.4	2.2	r
Apr 20	o.c. 25 %	35.8	1.3	35.5	35.9	2.6	r
May 04	o.c. 25 %	34.1	0.7	33.6	33.9	1.6	r
Apr 27	o.c. 25 %	35.1	1.4	34.7	35.5	2.7	r

Control							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
May 11	o.c. 100%	27.6	1.1	28.9	28.9	2.7	f
Aug 01	o.c. rain	28.9	0.4	29.9	29.0	1.1	f
Aug 01		28.9	0.3	29.9	29.0	0.8	f
May 18	cloudless	37.8	1.3	37.5	38.1	3.2	f
Jul 06	cloudless	31.7	1.2	31.6	31.7	3.2	f
Jul 06		31.7	0.8	31.6	31.7	1.9	f
May 25	cloudless	30.9	0.5	31.4	31.5	1.4	f
Aug 12	o.c. 100 %	29.4	0.9	29.9	29.7	2.2	f
Mar 16	o.c. 100%	32.6	0.6	31.2	31.4	1.6	f
Feb 24	cloudless	32.5	0.6	30.8	32.7	1.5	f
Mar 02	cloudless	33.1	1.0	32.2	32.6	2.3	f
Aug 12	o.c. 100 %	29.4	1.0	29.9	29.7	2.5	f
Apr 13	cloudless	38.1	0.2	37.1	37.8	0.5	f
Mar 23	cloudless	37.9	0.4	36.8	37.6	1.0	f
Jul 13	o.c. 100%	26.4	0.5	26.5	26.4	1.6	l
Jul 20	cloudless	28.9	0.4	28.7	28.4	1.1	l
Jul 27	o.c. rain	28.6	1.2	29.7	28.7	2.5	l
Jul 27		28.6	0.9	29.7	28.7	2.2	l
Jul 20	cloudless	28.9	0.5	28.7	28.4	1.3	l
Jul 20	cloudless	28.9	0.3	28.7	28.4	0.9	l
Jun 22	cloudless	32.3	0.3	32.0	32.2	1.2	l
Jun 15	cloudless	32.1	0.2	32.2	32.4	0.9	l
Jun 29	cloudless	28.7	0.4	29.2	29.1	1.4	l
Jul 13	o.c. 100%	26.4	1.0	26.5	26.4	2.4	l
Jul 13	o.c. 100%	26.4	0.7	26.5	26.4	1.9	l
Apr 06	cloudless	33.1	1.7	32.1	32.6	3.2	r
Mar 09	o.c. 100%	33.6	0.8	31.8	33.4	1.9	r
Apr 20	o.c. 25 %	35.8	1.3	35.5	35.9	2.8	r
May 04	o.c. 25 %	34.1	0.2	33.6	33.9	0.6	r
Apr 27	o.c. 25 %	35.1	1.5	34.7	35.5	3.0	r

Chez le Vieux

Slotted with Top							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
Mar 09	o.c. 100%	28.9	1.0	29.3	29.2	2.1	b
Jun 29	cloudless	30.7	0.6	32.2	32.7	1.1	f
Jun 29	cloudless	30.7	0.4	32.2	32.7	1.0	f
Mar 16	o.c. 100%	29.2	0.3	29.6	28.9	0.9	f
Apr 06	cloudless	29.1	1.6	29.5	28.7	3.5	l
Apr 27	o.c. 25%	31.8	0.2	32.1	32.1	0.8	l
Mar 01	cloudless	29.8	0.5	30.1	30.3	1.3	l
Mar 23	cloudless	37.3	0.5	37.7	37.5	1.7	l
Apr 13	cloudless	32.6	0.1	33.1	33.0	0.5	r
Apr 20	o.c. 25%	33.2	2.0	33.4	33.6	4.5	r
Feb 24	cloudless	27.2	0.5	28.1	28.9	1.9	r
Jun 03	cloudless	31.4	0.3	31.7	31.9	1.2	r
Jun 15	cloudless	34.7	0.4	35.4	35.6	1.1	r
Jun 15	cloudless	34.7	0.9	35.4	35.6	2.2	r
Jun 22	cloudless	34.8	0.2	36	35.4	0.7	r
Jun 22	cloudless	34.8	0.4	36.0	35.4	1.1	r
May 04	o.c. 25%	31.3	2.2	31.7	31.8	5.4	r
May 11	o.c. 100%	28.6	1.3	29.2	28.2	2.8	r
May 18	cloudless	32.4	0.6	32.9	33.1	2.0	r
May 25	cloudless	35.2	1.4	35.6	36.3	3.1	r

Control							
Date	Ambient Conditions	Ambient Temp.	Ventpipe Velocity m/s	Ventpipe Temp. °C	Latrine Temp. °C	Wind Velocity m/s	Wind Direction
Jun 29	0.94	30.7	0.9	32.2	32.7	1.8	f
Jun 29	0.94	30.7	0.6	32.2	32.7	1.3	f
Jul 06	0.94	28.7	1.2	28.7	28.6	4.1	r
Jul 06	0.94	28.7	0.2	28.7	28.6	1.0	r
Jul 06	0.94	28.7	0.4	28.7	28.6	1.3	r
Jul 13	0.94	25.9	1.7	25.6	24.9	6.0	l
Jul 13	0.94	25.9	1.0	25.6	24.9	2.9	l
Jul 13	0.94	25.9	1.5	25.6	24.9	4.8	l
Jul 20	0.94	31.3	1.0	32.8	31.8	2.8	l
Jul 20	0.94	31.3	0.2	32.8	31.8	0.9	l
Jul 20	0.94	31.3	0.1	32.8	31.8	0.6	l
Jul 27	0.94	28.1	0.5	29.9	28.4	1.6	l
Jul 27	0.94	28.1	0.6	29.9	28.4	1.9	l
Jul 27	0.94	28.1	0.4	29.9	28.4	1.2	l
Aug 01	0.94	27.7	0.1	28.3	28.0	0.2	l
Aug 01	0.94	27.7	0.3	28.3	28.0	1.1	l
Aug 01	0.94	27.7	0.2	28.3	28.0	0.7	l
Aug 12	0.94	28.1	0.7	29.8	28.4	2.1	l
Aug 12	0.94	28.1	0.5	29.8	28.4	1.8	l
Aug 12	0.94	28.1	0.8	29.8	28.4	2.4	l

Appendix E: Regression Analysis

Ecole Tanghin-Taambila Bloc A

Side Wind

	a	b	r	Δ% 5 m/s
Control	-0.0667	0.3258	.9886	-
Div. 25 cm	-0.0849	0.3394	0.9651	3.20
Div. 35 cm	0.0297	0.2989	0.9645	1.52
Slotted no top	-0.4068	0.5422	0.9693	47.50
Slotted	-0.4240	0.5314	0.9904	42.94

Front Wind

	a	b	r	Δ% 5 m/s
Control	0.0498	0.3879	0.9887	-
Div. 25 cm	0.0064	0.3920	0.9857	-1.14
Div. 35 cm	-0.0058	0.4089	0.9894	2.49
Slotted no top	-0.3605	0.6628	0.9919	48.48
Slotted	-0.1266	0.4365	0.9884	3.36

Back Wind

	a	b	r	Δ% 5 m/s
Control	0.1135	0.2299	0.9778	-
Div. 25 cm	0.0665	0.2348	0.9847	-1.79
Div. 35 cm	0.0978	0.2389	0.9667	2.32
Slotted no top	-0.3327	0.4508	0.9912	52.11
Slotted	-0.1863	0.4179	0.9789	50.66

Ecole Tanghin-Taambila Bloc B

Side Wind

	a	b	r	Δ% 5 m/s
Control	-0.1700	0.2796	0.9741	-
Venturi 20 cm	-0.0886	0.3548	0.9987	37.27
Venturi 15 cm	0.1462	0.2661	0.9716	20.29
Venturi 10 cm	0.1055	0.2589	0.9283	14.01
Single Venturi	-0.0041	0.3370	0.9733	36.92

Front Wind

	a	b	r	Δ% 5 m/s
Control	0.1116	0.2722	0.9780	-
Venturi 20 cm	0.2999	0.3579	0.9902	41.87
Venturi 15 cm	0.1431	0.3314	0.9753	22.22
Venturi 10 cm	0.080	0.3864	0.9589	36.58
Single Venturi	0.1404	0.3058	0.9945	13.37

Back Wind

	a	b	r	Δ% 5 m/s
Control	0.1374	0.1810	0.9898	-
Venturi 20 cm	0.2288	0.2515	0.9714	42.59

Venturi 15 cm	0.2447	0.1998	0.9936	19.30
Venturi 10 cm	0.2992	0.1697	0.9961	10.11
Single Venturi	0.2252	0.2300	0.9514	34.83

Ecole Dagnoin Bloc A
Side Wind

	a	b	r	Δ% 5 m/s
Control	-0.1841	0.4785	0.9550	-
Slotted no top	-0.3947	0.7528	0.9850	52.55
Slotted	-0.4652	0.7770	0.9812	54.85
Venturi 10 cm	0.0261	0.5022	0.9929	14.88
Single Venturi	0.0051	0.6080	0.9805	37.87

Front Wind

	a	b	r	Δ% 5 m/s
Control	-0.5097	0.6498	0.9765	-
Slotted no top	-1.1989	1.0358	0.9949	45.52
Slotted	-0.9416	0.9874	0.9916	46.10
Venturi 10 cm	-0.2102	0.6450	0.9804	10.22
Single Venturi	-0.3384	0.7946	0.9988	32.89

Back Wind

	a	b	r	Δ% 5 m/s
Control	-0.2840	0.2830	0.9930	-
Slotted no top	-0.2080	0.5480	0.9920	49.28
Slotted	-0.0963	0.5331	0.9860	51.35
Venturi 10 cm	0.4373	0.2894	0.9850	11.00
Single Venturi	0.4308	0.3773	0.9953	36.50

Ecole Dagnoin Bloc B
Side Wind

	a	b	r	Δ% 5 m/s
Control	-0.0950	0.2758	0.9865	-
Div. 25 cm	0.0436	0.2420	0.9785	-2.36
Div. 35 cm	0.0172	0.2657	0.9898	4.81
Slotted no top	-0.3342	0.4522	0.9853	50.11
Slotted	-0.3287	0.4507	0.9874	49.92

Front Wind

	a	b	r	Δ% 5 m/s
Control	0.0394	0.4531	0.9785	-
Div. 25 cm	0.4177	0.4371	0.9542	1.09
Div. 35 cm	0.5690	0.3825	0.9752	-3.64
Slotted no top	-0.2229	0.8559	0.9729	57.54
Slotted	-0.4522	0.8689	0.9857	51.16

Back Wind

	a	b	r	Δ% 5 m/s
Control	0.3455	0.3065	0.9909	-
Div. 25 cm	0.4224	0.2912	0.9788	0.03
Div. 35 cm	0.2129	0.3457	0.9801	3.40
Slotted no top	-0.6490	0.7022	0.9945	52.42
Slotted	-0.1542	0.5715	0.9966	43.96

Cité de l'avenir
Side Wind

	a	b	r	Δ% 5 m/s
Control	0.0004	0.3046	0.9879	-
Slotted no top	-0.1683	0.4672	0.9850	42.29

Cité AN II
Side Wind

	a	b	r	Δ% 5 m/s
Control	-0.0699	0.4968	0.9879	-
Venturi 15 cm	-0.0252	0.5970	0.9707	22.61

Dassango
Back Wind

	a	b	r	Δ% 5 m/s
Control	0.0203	0.1749	0.9706	-
Slotted	-0.1237	0.2753	0.9900	43.53

Pissi
Side Wind

	a	b	r	Δ% 5 m/s
Control	-0.3072	0.5818	0.9816	-
Div. 25 cm	-0.2091	0.5734	0.9849	2.16

Pissi
Front Wind

	a	b	r	Δ% 5 m/s
Control	-0.0174	0.4071	0.9932	-
Div. 25 cm	-0.0883	0.4418	0.9698	5.09

Appendix F: Questionnaire

QUESTIONNAIRE
LE NIVEAU DE SATISFACTION ET D'ENTRETIEN DES LATRINES A FOSSE VENTILEE

Enquêteur ....
Date ....
Heure début ....
Heure fin ....

A SOCIAL-ECONOMIQUE

A1. SECTEUR ....

Sous-secteur ....

A2. Coordonnées de l'enquête

Nom .... Facultatif
Prénom ....
Sexe ....
Age ....
Profession (public,privé,informel) ....

A3. Religion

Musulman ☐

Chrétien ☐

Animiste ☐

.... ☐

A4. Groupe d'appartenance ethnique

Mossi ☐

Dioula ☐

Peulh ☐

Foulga ☐

Gourmantché ☐

Bissa ☐

Dafing ☐

Dagari ☐

Autre (précisez) ☐

A5. Situation de famille

Célibataire ☐

Marié ☐ Nombre d'épouses ☐

Veuf (veuve) ☐

A6. Loyer

Propriétaire et loge chez lui ☐

Locataire ☐ Loyer versé ....FCFA

Occupant gratuit (statut) - frère, cousin, employé domestique ☐

A7. Combien d'années avez-vous occupé votre domicile? ☐ ans

A8. Niveau de scolarisation

Primaire ☐

Secondaire ☐

Supérieur ☐

Alphabétisé (indiquer la langue locale) ....

A9. Nombre de personnes vivant dans le ménage

- Hommes (à partir de 20 ans) ☐
- Femmes ☐
- Enfants (de 0 à 19 ans) ☐

A10. Dépenses familiales mensuelles .... FCFA

A11. Qualité de l'habitat (matériaux utilisés)

- Banco ☐
- Sémi-dur ☐
- Dur ☐

A12. Equipement

- Eau courante ☐
- Electricité ☐
- Téléphone ☐
- Vélo ☐
- Mobylette ☐
- Voiture ☐
- Radio ☐
- Télévision ☐

B. LATRINES

B1. Depuis quand possédez-vous votre latrine? année ☐

mois ☐

B2. Quel type de latrine existe chez vous?

simple fosse ☐

double fosse ☐

B3. Depuis que votre latrine fonctionne, dites-nous ce que vous utilisez pour la toilette anal

Eau ☐

Papier ☐

Cailloux ☐

Bois ☐

.... ☐

B4. Par quel canal avez-vous été informé(e) de l'existence de cette technologie?

Par les agents de CREPA ☐

Par la presse écrite ☐

Par la télévision nationale ☐

Au cours d'un séminaire ☐

Autres sources d'information (précisez)

Faites-nous un petit commentaire sur la manière dont vous avez été informé(e)

B5. Quelles ont été les raisons de votre choix selon qu'il s'agit d'une VIP?

B6. a) Comment avez-vous réalisé votre latrine?

Avec l'appui du CREPA ☐

Avec l'appui d'une autre institution ☐

b) Quelle a été

	votre contribution?	celle de l'institution
Technique	☐	☐
Financière	☐	☐
Matérielle	☐	☐
Fouille (exécution)	☐	☐
Confection de briques	☐	☐
Main d'oeuvre	☐	☐
....	☐	☐
....	☐	☐

B7. Quel a été le coût total de la réalisation de votre latrine?

.... FCFA

B8. a) Votre latrine, vous pose-t-elle des problèmes?

Odeurs	oui ☐	non ☐
Mouches	oui ☐	non ☐

Autres problèmes ....

....

....

b) A quel moment de la journée les odeurs sont-elles la plus incommodantes?

- matin ☐
- après midi ☐
- soir ☐
- nuit ☐
- toujours la même ☐

c) Qu'avez-vous fait pour y remédier ?

B9. Si vous pouvez réhabiliter votre latrine pour remédier les problèmes, combien de francs êtes-vous prêt à y consacrer?

- de 500 à 2.500 FCFA ☐
- de 2.500 à 5.000 FCFA ☐
- de 5.000 à 7.500 FCFA ☐
- de 7.500 à 10.000 FCFA ☐
- plus (précisez) ....

B10. Depuis l'installation, environ combien de personnes vous ont posé des questions sur votre latrine concernant:

- Mode de fonctionnement ☐ personnes
- Son prix de revient ☐ personnes
- .... ☐ personnes

B11. a) Des personnes vous ont-elles posés des questions sur la démarche à entreprendre pour obtenir de telles réalisations?

☐ personnes

b) Si oui, peut- on avoir leurs adresses?

Nom Secteur

B12. Combien de personnes ont réalisé leurs latrines en s'inspirant de la votre?

☐ personnes

B13. a) Au total, êtes-vous satisfait(e) de votre latrine?

Oui ☐ Non ☐

b) Si non, que suggérez-vous au CREPA

QUESTIONNAIRE
LE NIVEAU DE SATISFACTION ET D'ENTRETIEN DES LATRINES A FOSSE VENTILEE

Enquêteur	....
Date	....
Heure début	....
Heure fin	....
Secteur	....
Sous-secteur	....

Etat de la latrine

1. **Location**

Distance de la maison .... m
Distance de la mur la plus près .... m
Hauteur de la mur la plus près .... m

Obstructions près du tuyau? oui ☐ non ☐
Commentaire

Carte du enclos

2. **Superstructure**

	Bon	Mauvais	Commentaire
porte	☐	☐	....
toit	☐	☐	....
murs	☐	☐	....
			....

3. **Dalles**

	Bon	Mauvais	Commentaire
Extérieures	☐	☐	....
Intérieures	☐	☐	....
			....

4. **Tuyau**

	Bon	Mauvais	Commentaire
Verticalité	☐	☐	....
Grille	☐	☐	....
Scelle	☐	☐	....
			....

5. **Propreté**

	Bon	Mauvais	Commentaire
Dalles	☐	☐	....
Odeurs	☐	☐	....
Mouches	☐	☐	....
			....

6. La fosse, est-elle presque pleine?

☐ 1/4 pleine
☐ 1/2 pleine
☐ 3/4 pleine
☐ pleine

Appendix G: Latrine Construction Costs

Double Pit Household Latrine

		Amount	Unit (CFA)	Total (CFA)
Pit	m^3 excavation	4.4	1500	6,600
Pit Walls	15 cm bricks	85	135	11,475
	sacks of cement	1.5	4000	6,000
	m^3 gravel	0.1	3200	320
	m^3 sand	0.4	3200	1,280
Cover Slabs	10 mm rebar	1	3000	3,000
	6 mm rebar	3.5	1200	4,200
	sacks of cement	1.5	4000	6,000
	m^3 sand	0.15	3200	480
	m^3 gravel	0.3	3200	960
Cabin	15 cm bricks	146	135	19,710
	sacks of cement	2	4000	8,000
	m^3 sand	0.5	3200	1,600
	corrugated iron	5	3000	15,000
	L-bar	2	750	1,500
	tacks	10	20	200
	m PVC piping	3.8	3000	11,400
Total				97,725

521 CFA = $US 1

Communal Latrine (9 cubicle)

		Amt	Unit (CFA)	Total (CFA)

Pit	m^3 excavation	60	1500	90,000
Pit Walls	15 cm bricks	900	135	121,500
	sacks of cement	42	4000	168,000
	m^3 gravel	21	3200	67,200
	m^3 sand	17	3200	54,400
Cover Slab	10 mm rebar	13	3000	39,000
	6 mm rebar	50	1200	60,000
	rolls of wire	2	10000	20,000
	m^3 water	3.5	650	2,275
	labour	1	150000	150,000
Cabin	15 cm bricks	1400	135	189,000
	sacks of cement	36	4000	144,000
	m^3 sand	10	3200	32,000
	corrugated iron	20	3000	60,000
	doors	9	10000	90,000
	screen wall doors	2	25000	50,000
	m PVC piping	15	3000	45,000
Total				1,382,375

521 CFA = $US 1

Cost of Accessory Fabrication

Venturi Accessory

Two Bowl Design		Single Bowl	
Round iron bar	200 CFA	1 bowl	300 CFA
2 bowls	600	Screws	100
Screws	100	Labour	200
Labour	900		
TOTAL	1800 CFA	TOTAL	600 CFA

Slotted Accessory

PVC piping	1250 CFA
Labour	2000
TOTAL	3250 CFA

Divergent Accessory

Tinplate	500 CFA
Labour	1500
TOTAL	2000 CFA

Note 521 CFA = $US 1

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