LOW FLUSH WATER CLOSETS IN BUILDINGS AND THEIR EFFECTS IN THE DRAINAGE SYSTEMS

C. T. Ganesan
Department of Civil Engineering
University of Botswana
Gaborone, Botswana

Water scarcity in arid and semi-arid countries such as Botswana; call for judicious planning and economic use. In this connection many water saving components and appliances have been devised. One such system for example is the partial flushing unit fitted to water closets, which cause the volume and flow of water in the drainage system decrease, compared with ordinary systems. To maintain a sufficient transportation in drainage pipes connected to low flush water closets (water closets with a flow less than 6 litres per flush) it is necessary to follow a set of rules concerning slope on pipes, length of pipes, type and place of junctions and bends, which are different from rules used in conventional systems. Author suggests that in countries like Botswana where availability of water is unpredictable only 4 litres per flush can be allowed for successful operations. In this paper certain rules for design and dimensioning drainage pipes for water saving systems are proposed. Besides the paper presents a complete general survey of the influence of branches and bends illustrated by means of drawings and descriptions.

1 INTRODUCTION

It is expected that the present 1.3 million population of Botswana is doubled in the next 30 years, with 30% more people staying in urban areas as compared to 20% now. Most of the water for Botswana originates from rainfall, which is erratic and unreliable. While there is an average annual rainfall of 450 mm the estimated annual evaporation is 2000 mm. Most of the rivers are in the eastern part of the country and are ephemeral. The only perennial systems are the Chobe and Okavango rivers in a less densely populated area in the northwest region. The ephemeral systems have an estimated yield of 1200 million cubic meters per year of which 19% is already stored in man made reservoirs. The ground water on which about 80% of the population and livestock depends, has an estimated extractable volume of 100 000 million cubic meters, but only 1% of this is rechargeable by rainfall. This data [1] shows that one should have increased consciousness of the necessity of reducing the water consumption by using water saving devices and methods. The other alternative method of reduced usage of water is for the concerned departments to increase the taxes on water and sewage disposal, which ofcourse, they are already doing!

In some of the industries like breweries water saving measures have been developed and implemented aiming at changing bad user habits and proposals for installation of simple water saving devices. Concerning dwelling houses and offices in Botswana campaigns have to be carried out with the objectives of informing the consumers of do-it-yourself measures to reduce the water consumption. Such campaigns must have primarily aimed at changing bad user habits and proposals for installation of simple water saving devices. Ref.2 shows that such campaigns followed in Copenhagen were successful and from 1989 when the campaigns started, the water consumption per inhabitant have gone down from 169 litres /person/day to 130litres/person/day. One of the biggest savings that can be obtained without the awareness of the consumer is obtained by using water closets with small flush water volumes. It is worth to mention here; about 20% of the water consumption are used for flushing the water closets.

The present building legislation of Botswana [2] gives the design rules for house drains based on traditional appliances i.e., water closets with flush water volumes of 6 litres. This means that no problems will arise in existing house drains when old water closets are replaced with 6 or 4 litres per flush. Water closets with double flush where the small flush is 3 litres and big flush is 6 litres are also permissible, since it is expected that at least 2 to 3 times a day the big flush will be used. According to the author's suggestion of using water closets with 4 litres per flush it is advisable to fit flush amplifier at the bottom of the stack. (Fig. 1 and 2). Hence, water closets with a flush volume of 3 litres (half of the big flush) can only be used in houses with several floors and with a basement, where the "flush amplifier" is placed at the bottom of the stack. For single family houses a water closet with a flush volume of 4 litres can be used. [3]

2 FLUSH AMPLIFIERS

Figure 2 (a,b and c) shows working principles of flush amplifier. The full capacity of the flush amplifier is normally double the capacity of low flush type water closet but not less than 8 litres. When a flush is made with a low flush water closet in one of the flats in the multi-storied building a volume of 3 0r 4 litres of water with fecal matter flows vertically down into the

amplifier, refer arrow shown in fig.2(a) and stays in the inlet chamber till subsequent flow of water from other sanitary appliances like the bath tub or from kitchen units fill the remaining portion of the chamber. The excess flow, if any after filling will be drained through the by pass pipe initiating a syphonic action.. Thus when the inlet chamber is full, syphonic action is started. (fig.2b). The velocity is increased with down suction effect and the chamber is emptied (fig.2c). The amplifier fitted stack system increases the transportation distance (explained in the next paragraph) eliminating the chances of blockage in the main sewer within the limits of domestic layout.

3 TRANSPORTATION DISTANCE

In house drains a flow will only occur when sanitary appliance is activated. The transportation of feces/paper takes place as follows; the water is stemmed behind the faces/paper and pushes them forward. Eventually the water will flow passing over these materials after moving them some distance until the next flow of water pushes it further through the system. After a certain number of flushes the faces/paper has reached to a point from where it does not move further no matter the number of flushes made. This distance is the so-called *transportation distance* and it depends on the design of the sewer systems. In a system with many changes of direction and a small gradient the transportation distance is short, where it is longer in a system with a steep gradient and a straight pipe. [3].

The transportation distance in a sewer system depends on several factors:

- The volume of flush water from the water closet.
- The supply of continuous flow(discharge from other sanitary appliances)
- The design of house drain – gradient, materials, hydraulic resistance in elbows, junctions etc.

Figure 3 illustrates the transportation distance in a house drain that is exposed to the flush from water closets with different flush water volumes. The transportation distances are plotted for different continuous water flows in drain- pipe. The longer the transportation distance is, the less is the risk of blocking. If the transportation distance is long, the feces/paper will probably move so far through the system that it will later be moved on by the flow from other sanitary appliances like bath tub or kitchen units. [4].

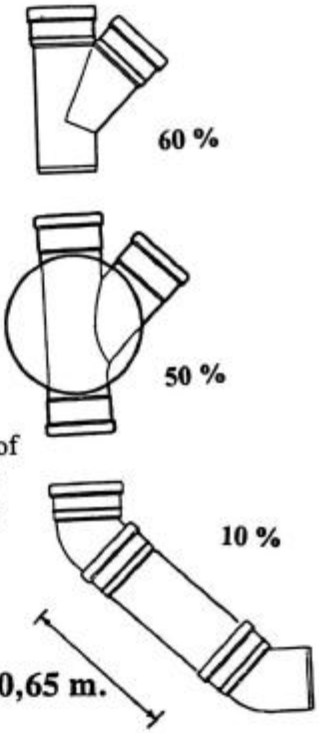

Fig 3 The effect of single Hydraulic resistance on the reduction of Transportation Distance.

4 FLUSH WATER VOLUMES FROM WATER CLOSETS

The transportation distance in the case of water closets with flush volumes below 6 litres is considerably shorter than that of water closets with volume of 6 litres. The following table shows the experimental result [2] on transportation distance for a single flush with continuous inflow on different capacity water closets. The drainpipe 200 mm diameter leading from is laid in a gradient of 1 in 20. More details of the experimental set up can be found in the paragraph 8.

WC capacity(l)	Transportation distance(m)
3	5.2
3.5	6.5
3.0	7.2
6.0	8.0
7.0	8.5
7.5	9.5

5 SUPPLY FROM CONTINUOUS WATER FLOW

The supply of water from other sanitary appliances can extend the transportation distance, especially if water is supplied over a period of time, e.g. from a washing machine and dish washer or bath tub and shower.

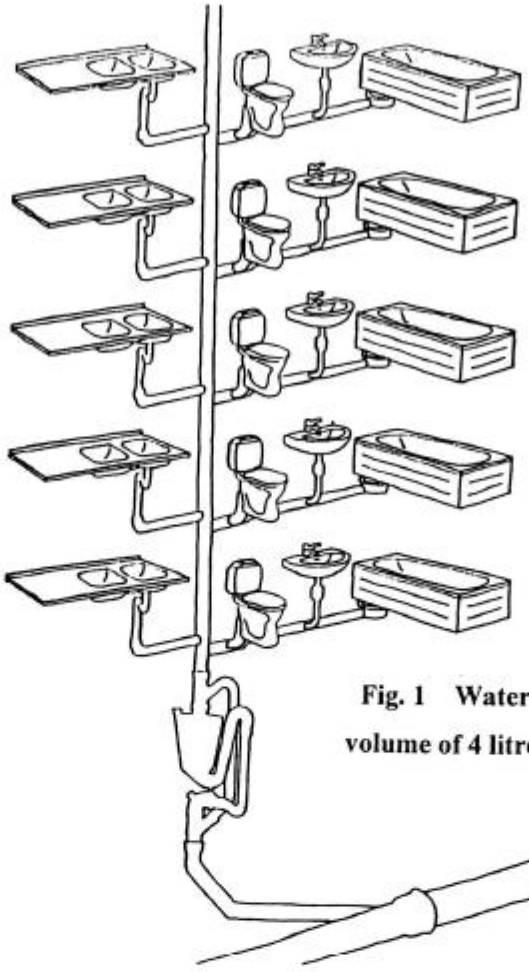

Fig. 1 Water closets with flush volume of 4 litres with Flush amplifier

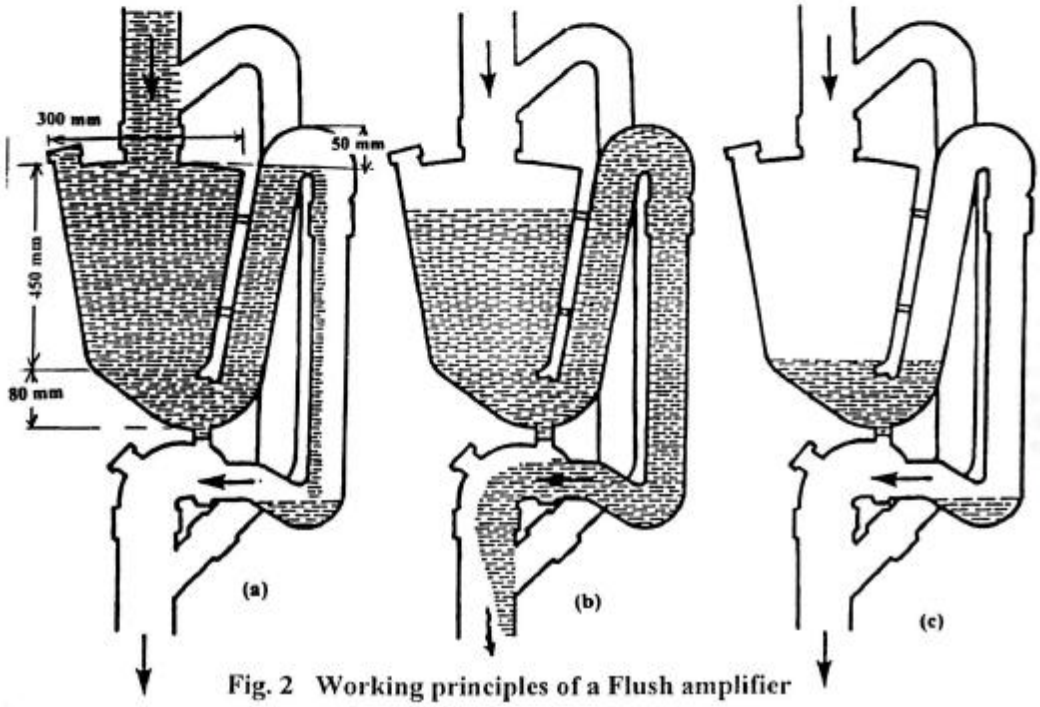

Fig. 2 Working principles of a Flush amplifier

When the distance from the water closet to other waste water flows is short, the risk of blocking in the following pipe section will be reduced.

6 THE DRAIN SYSTEM

Drain system can be built of materials with different roughness of the surface of short or long pipes and comprise many different pipe sections and various degrees of gradients. The transportation distance depends on the gradient, i.e. the higher the gradient the longer the transportation distance. Also the pipe material is important, because the transportation distance in pipes with less roughness of the surface is longer than that of pipes with higher roughness of the surface. Furthermore, the quality and the number of joints are of consequence. A joint is the same as a hydraulic resistance that may reduce the transportation distance. Especially the quality of joints close to branch pipes elbows and manholes should be considered, because the combination of poor jointing and other hydraulic resistance can reduce the transportation distance drastically.

7 HYDRAULIC RESISTANCE

Hydraulic resistances in the sewer system influence greatly the transportation distance. Horizontal pipe junctions and manholes with lateral inlets can reduce the transportation distance by 50%. Elbows can also reduce the transportation distance, but less than branch pipes and manholes. Sharp elbows have greater effect in reducing the transportation distance. Figure 4 shows regulations for the effect of a single hydraulic resistance on the reduction of transportation distance. Junctions and manholes influence the transportation distance because they change the cross section of the flow profile in the pipe. It is important that the change in cross section is as minimum as possible and branch pipes should have wide obtuse angle at the junction. The velocity of water very much reduced at the fat bottomed manholes causing the faeces/paper to remain lying there. In junctions and manholes where the diameter of the connecting pipe is smaller than the main drain the transportation distance is reduced by 50%. [6].

8 EXPERIMENTAL SETUP AND OBSERVATIONS

Experiments were conducted using 200 mm diameter plastic pipe of a total length of 22 m laid in 1 in 20 gradient with water closet connected at the starting point. Tests were conducted with water closets of 3, 4 and 6 litres flush volume capacities. Sponge cubes 15 mm side, wound with thin copper wire was used as fecal matter combined with toilet tissue balls. Flow rate was measured with a 200 x 100-venturi meter. Research work is still in progress with different size and shapes of the amplifier units for maximum efficiency. Figure 4 shows that variation of flow within 10 seconds after flushing allowing inflow into the cistern. Figure 5 shows the transportation distance measured after flushing at different flow rates with constant inflow into the cistern. It can be seen that 4 litre WC has a maximum transport distance of 7.2 m with a flow accelerated up to a maximum of 1.8 lps. This TD is without the amplifier. In a real stack drain system with a suitable amplifier fitted as shown in fig.2 a transport distance nearly double this value can be achieved.

9 DESIGN RULES PROPOSED

The discussions made so far about the transportation distance and the hydraulic resistance result in the following proposals of design rules for water closets of 4 litre capacity and house drains before connecting it with the municipal sewer.

- The minimum gradient of the drain system must be 1 in 20.
- Drain that only service water closets must have a length of maximum 3 m from the water closet to a connection to other pipes that carry wastewater from other sanitary appliances.
- The connection from each dwelling house to the main sewer must be spaced to a maximum of 25 m long measured horizontally.
- Drains that carry wastewater from only water closets or from one dwelling must have maximum two elbows of maximum angle 45°. The changes of direction immediately after the water closet and at the junctions are not included.[6]
- Drains that carry wastewater from one dwelling must have maximum one lateral connection in the form of one junction or one manhole with one lateral connection. Manhole with two lateral connections must not be used.
- The drains shall be made of plastics
- Manhole bottoms shall be as per the British Standard Specifications or South African Standards
- Drains which carry waste water from more than one dwelling must have a gradient of minimum 1 in 20 and can be up to 50 m long until connection to ventilated sewer systems with a minimum diameter of 150 mm or to sewer systems that carry waste water from at least 17 dwellings with water closets with 4 litres flush water volumes.[7]

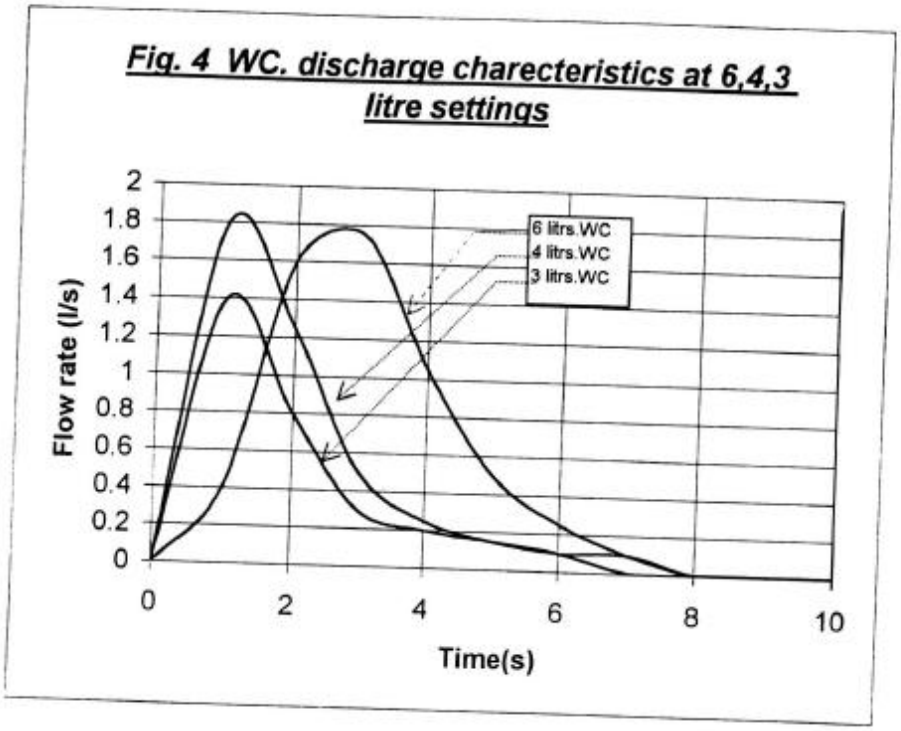
Fig. 4 WC. discharge charecteristics at 6,4,3 litre settings
Flow rate (l/s)
Time(s)
6 litrs.WC
4 litrs.WC
3 litrs.WC
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
2
4
6
8
10

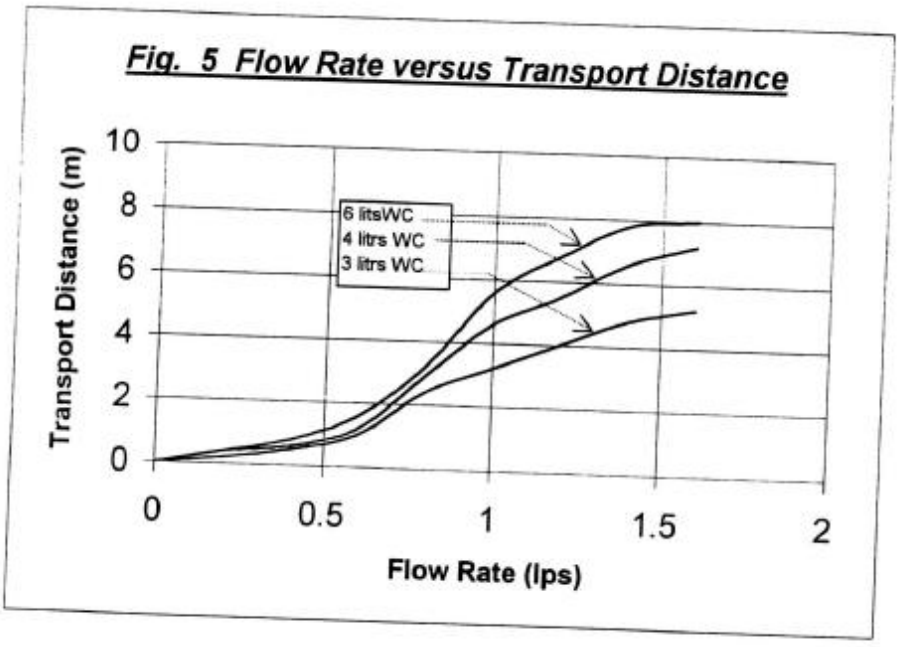
Fig. 5 Flow Rate versus Transport Distance
Transport Distance (m)
Flow Rate (lps)
6 litsWC
4 litrs WC
3 litrs WC
0
2
4
6
8
10
0
0.5
1
1.5
2

These rules as proposed by ETA – Denmark (European Technical Approval) are shown in figure 6

10 CONCLUSION

Hydraulic resistance and transportation distance is very important properties deciding the effectiveness of building drainage system with low flush volume type of water closets. For the purpose of saving water, blockage of house drains can not be permitted. With a suitable amplifier fitted at the end of stack having 4 litres flush volume capacity about 14 m of transportation distance can be achieved without any problem of blockage in the house drain system.

ACKNOWLEDGEMENT

The author is grateful to Professor Fumitoshi Kiya, chairman, 1997 CIB-62 Symposium on Water supply and drainage for buildings, Japan for permitting to reproduce the schematic diagrams, figures 1 and 2 shown in this paper.

11 REFERENCES

1. ASME A112, 18.3 "Performance requirements for back flow prevention devices and systems in plumbing fixture fittings" American Society of Mechanical Engineers, New York, NY., 1966

2. Faldager D, and Ganesan C.T "Effects of water closets on transportation in the drainage system". CIB-62 Symposium on Water supply and drainage for buildings, Japan, 1997

3. Griggs, Pitts, Hall and Shouler, "Water conservation: A guide for the design for the design of low flush water closets". Building research Establishment IPS/97 Part 1 CRS. London 1997.

4. Griggs, Hall and Shouler, "The effects upon drainage systems connected to water closets of proposed changes to the water bylaws of England and Wales", Buildings Research Establishment, Gatson, Watford, WD2 7JR, U.K. Sept 1997.

5. Khupe B.K. "Integrated water resources management in Botswana". Opening address for the workshop. University of Botswana and Rural Industries Innovation Centre, Botswana and sponsored by SIDA, 18-19 March 1994

6. Thomas O. Konen. "Impact of water conservation of interior plumbing" Technical proceedings of the ASPE convention. American Society of plumbing engineers, west lake village, California, USA. 1994.

7. Wise F.E. "Water, sanitary and waste water services for buildings", B.T.Batsford limited, London 1989.

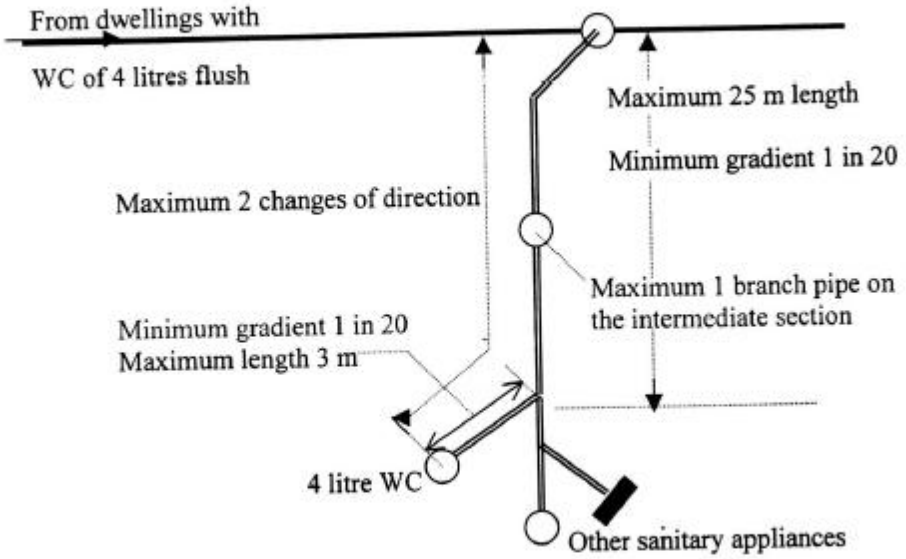

Fig. 6 Design rules for drains in the ground connecting 4 litres flush volume and for less than 17 dwellings.