Application of GSAP Microflush toilets: a sustainable development approach to rural and peri-urban sanitation

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Abstract

The Microflush-Biofil(MB) toilet system, a prototype marriage of a macro-organism enhanced aerobic digester and an innovative valve that flushes on just 150 cc of water has proven to be an effective sanitation solution for developing world tropical communities. This paper examines the sustainable elements of this technology. We present the approach of the Ghana Sustainable Aid Project in readying the technology for a decentralized approach in moving to a global scale. The challenges and opportunities associated with such an ambitious plan.
Keywords: rural sanitation, toilets, off-grid, closed systems, open source sanitation, sanitation credit, macro-organism enhanced digestion, aerobic digestion, microflush valve.

1 The prototype technology

Under a Grand Challenges Explorations Award from the Bill and Melinda Gates Foundation, the Ghana Sustainable Aid Project (GSAP) has successfully prototyped a marriage of two technologies, the Biofil Digester, designed by Kweku Anno, a Ghanaian engineer, and the (patent pending) Microflush valve, designed in the Department of Engineering-Physics-Systems at Providence College. The valve flushes on as little as 150 cc of water and results in an isolation of waste from human contact eliminating odors and disease-bearing flies. GSAP has incorporated the valve into multiple designs including a generic macro-organism enhanced aerobic digester, the GSAP Microflush(GMF) system, which can be fabricated using local skills and materials. Under the prototype field phase of the project, four single stall household-family (1H) level units, 1 5-stall school toilet (5S) and 1 10-stall public toilet (10P) have been constructed and closely monitored in Pokuase Village in Ghana. The locations are shown in Figure 1.

Figure 1: Locations of 5-stall School (5S), 10-stall Public, a 4 single stall Household toilets (1H) in Pokuase Village in Ghana.

Each of the systems is placed in different installation terrains within the village community. The four 1H systems have been functioning for over a year, one of these in fact for over 20 months, the 5S system for over a year and the 10P system for just a few months before we learned that it had not been properly prepared prior to use; it is now being re-installed.

A diagram of the GSAP Microflush(GMF) system is shown in Figure 2a. By design, each stall is fitted with a hand wash station, which is outfitted with a low-flow handle-less faucet aerator. We tested two types of aerators, a push button mechanically controlled timed release and a bar on-off design; these are shown in Figure 2b. While both function well; the screen in the push button version required cleaning every 4-5 weeks especially when the water source contained debris. This button in this version was also less likely to be in the stream flow for the entire hand-wash resulting in a low but measureable level of contamination.

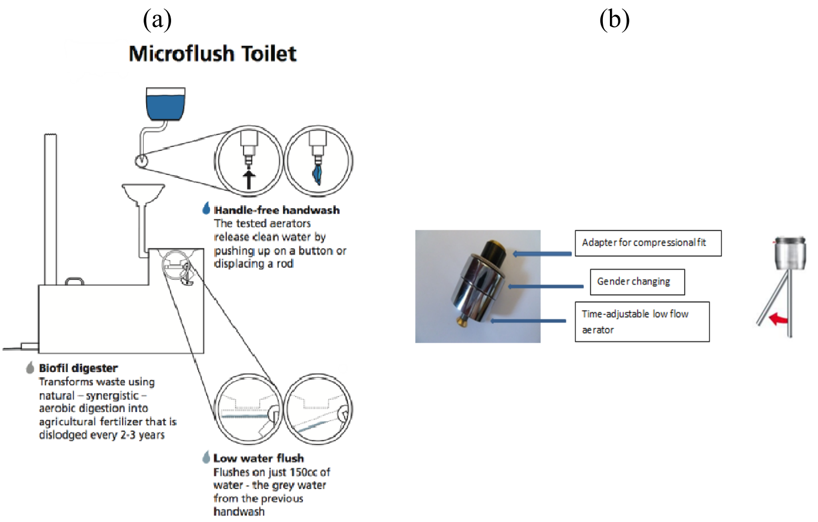

Figure 2: (a) Functionality of the GSAP Microflush toilet. (b) Handle-less aerator options used for handwashing.

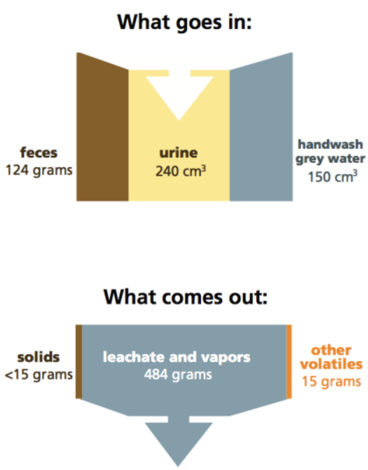

Figure 3: Inputs and outputs of a GMF toilet per user.

The greywater from hand washing is used for the ensuing flush of the toilet. When water is present in the pan-type Microflush valve, it provides a separation of waste from space and human contact thus controlling odors and eliminating flies. The waste is directly released to the digester bed which does a rapid separation of liquids from solids. The material flow is shown in Figure 3; a little more than .5 kg of input per average use results in less than 15 gms of solids. The liquid filtrate from 30 uses is less than 15 liters. In the prototype systems the filtrate is allowed to penetrate a small sandy leaching field. Current work in our laboratory is exploring 4 options for removing the pathogens from this relatively small volume of liquids.

The systems that have been running for some time are working as planned. Our original estimates were that dislodging/compost harvesting would take place every 2 years; it appears now that the 1H units will not require harvesting and restart until the 3rd year of operation as the mass reduction is higher than originally expected. The GMF process [1] and the advantages [2] of macro-organism enhanced aerobic decomposition of human waste are becoming well established.

We have then in the MB system an off-grid, low (grey) water consumption toilet that produces a useful, pathogen free solid residue product. The liquid filtrate is not separately processed in the prototype systems, but allowed to enter the environment much as the leachate from a conventional septic system is treated in a leaching field except that the volumes of leachate are greatly reduced in the MB system. Nevertheless, our toilet group in EPS is working on promising approaches to disinfecting the small quantity of leachate through SOLDIS (UV and thermal), urine sourced ammonia disinfection and slow sand filtering. Reports on these are forthcoming in other publications. With the inclusion of such disinfection technologies, the resulting liquids will be pathogen free but nutrient rich allowing for use in agriculture, cleaning/washing or safe discharge to the environment. Such a system is clearly sustainable especially in comparison to Western sanitation systems which take 1−2 gallons of potable water , mix it with our fecal waste before flushing it down a drain out of sight and out of mind through an (often decaying) network of sewer drains. The waste is moved to an energy intensive treatment plant that does primary, secondary and tertiary treatment while chemically treating the final liquid before it is discharged to recharge a watershed with lower quality water than that of what was originally taken.

The superiority of vermicomposting enhanced digestion over latrine-style pit systems in pathogen destruction and mass reduction is becoming more well-known [2]; while e-fetida lays an important part in our systems, we have also observed the positive impact of other macro-organisms that find favorable conditions (pH, temperature, C/N ratio, moisture and O_2 in the process)in the digester. Observe the temperature range overlaps of various macro-organisms with the GMF operating temperature range in Figure 4.

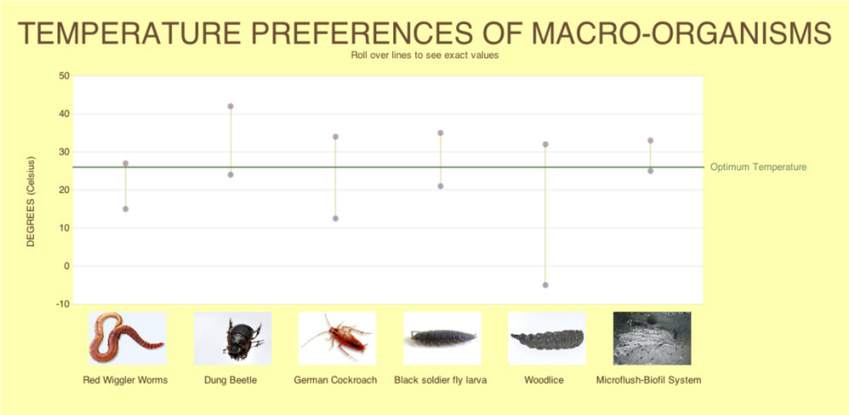

Figure 4: Temperature preferences for selected macro-organisms.

2 Contribution to hygiene, health and more

Much has been written about the connections between the condition of sanitation, mortality and morbidity, education (especially the education of girls), community development and nation building. The authors have recently

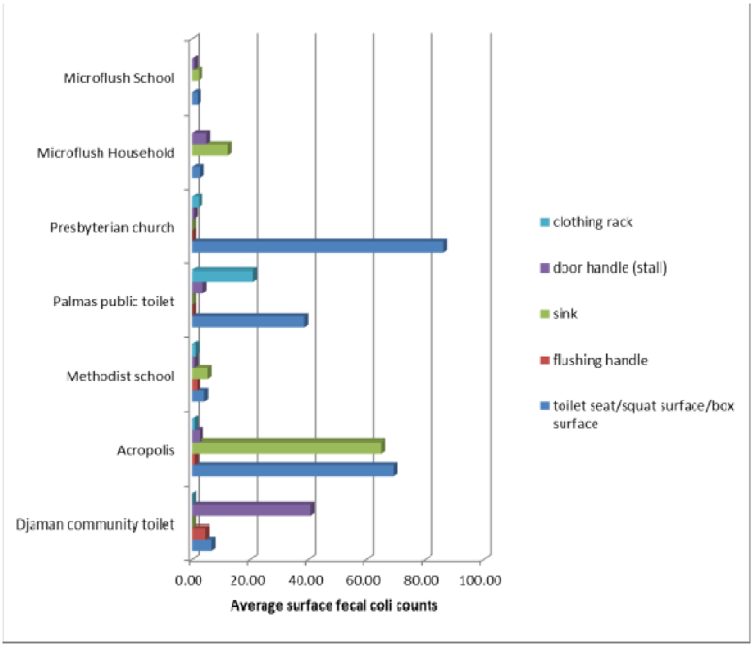

Figure 5: Fecal coli colonies from measurements taken on surfaces of Microflush and other community toilets.

reported on this [3]. Forty-one percent of the transmission of diahorreal disease, a leading cause of death in children, is transmitted at schools. The GSAP Microflush systems encourage a hand-washing habit as the grey water prevents the foul odors and disease bearing flies found in open toilet systems. Two of the most contaminated surfaces in toilets are the faucet and the stall door handles. The use of a handle-less water supply and the location of a sink in each stall virtually eliminates these two sources of contamination. Our studies of the prototype system included measurements of surface fecal coli counts in the 1H and 5S Microflush toilets and similar data taken for other systems in the Pokuase-GaWest community. Overall surface fecal coli colony results are shown in Figure 5. While a fuller report on these studies is part of another paper in progress, one has only to look at the stall door handle counts in these data to see the clear advantages of the Microflush technology.

3 Local density limits

The small and recoverable amount of water used, the valuable end-product solids and the hygienic environment suggest the basic elements of sustainability but at what local scale can the GMF system be installed? Capacity studies are under way but data on non-environmentally friendly anaerobic ‘pit’ systems suggest that the leachate influence will not exceed several meters [4] in average sand-clay soils in terrains that do not experience surface run-off. Indeed, non-flushing versions of the Biofil toilet have been successfully installed in dense peri-urban communities without noticeable effects. Nevertheless, the Civil-Hydrological modeling to determine such densities are sensitive to local soil and weather conditions. The density limits for systems supporting aforementioned on-site filtrate processing are not dependent on local conditions save for access to

Figure 6: Early prototype of the Microflush toilet.

sunlight for the SOLDIS options and physical security of the system. Instead the limitation is on the spatial footprint of the toilet and facility. The digester occupies a footprint of about 18 ft^2 and the facility does not add much to this footprint as the floor is basically the forward segment of the top of the digester unit. An early prototype is shown in Figure 6.

The aforementioned leachate processing options we are considering have preliminary designs that add less than 10ft^2. So the footprint is about 30 ft^2 for a 1H system that would be relatively closed save for the few liters of fresh water required for hand washing and that water would be ultimately recoverable for use in cleaning or agriculture. In rural communities where block sizes housing several families who would share a 1H toilet, the toilet would occupy less than 3% of the household compound.

4 Community-country-global- scaling of the technology

What model will best take the GSAP Microflush technology to community- country- and global scales? There are two extremes that are worth considering. The central production model (CPM) and the on-site fabrication model (OSF). The features of each scenario are summarized in Table 1.

Table 1: Features (*) Advantages (+) and Drawbacks (-) of the CPM and OSF models for scaling Microflush toilet technologies.

CPM	OSF
*Factory-centric production, fabrication, deployment, sales and maintenance with transshipment to user- community- country- sites.	*Decentralized locally made (small business) onsite with local supplies by trained craftsman and locally maintained.
+ High degree of quality control + Future benefits of mass production - High start-up costs in capacity building and tooling -Higher end-user costs (transportation, service, middlemen)	+ Contribute to the local economy + Very low cost to the end-user + Consistent with off-grid non-centralized philosophy +/- Challenge to implement the Microflush toilet technology with local materials, skills

For obvious reasons, the first prototypes followed the CPM approach; Biofilcom, located in Accra, was subcontracted to do this work in Ghana and it follows this factory centric model. Scaling up, especially outside the factory region, with this model poses problems on several levels. First, start up tooling and factory costs are high. Transportation and the need for middlemen in the supply chain create additional costs. For the prototype systems which were still in the same region as the factory, the price to the user was $1200 per 1H system. Amortization of mass-production tooling costs was not included in this figure. While the users of these prototypes are strong in their appreciation for the technology, the systems must have a much lower price-point to be accessible to the lowest two quintiles of the household income spectrum, i.e. those earning \$2–\$3 per day. The Toilet Group at the EPS Lab at Providence College is focusing on research development aimed at reducing costs. Much of the success thus far has been a result of using locally available skills and materials. (We have already removed over 35% of the costs and our current research promises a final product in the OSF model to be sold for under \$300 with an appropriate profit to the local craftsman/entrepreneur.) GSAP believes that the OSF community-centric approach not only makes the GMF toilets accessible to the target population, the poor, but also enhances the sustainability of the total solution. It eliminates excessive transportation costs, develops community economies and respects a community's culture.

5 Challenges and opportunities

The aforementioned OSF model is being piloted in central Ghana. It works as follows:

1. GSAP identifies not-for-profit partners in the host country community. Service organizations, NGOs, agencies, Church organizations, Peace Corps volunteers and individuals with a commitment to improving sanitation in their communities. The partner organization:
2. Identifies a local entrepreneur/craftsman who is anxious to learn how to construct and maintain GSAP-Microflush toilets.
3. Identifies a local microfinance organization which is willing to implement sanitation credit for GSAP Microflush ownership.
4. Assists/hosts GSAP in its training program.
5. Selects 2–3 initial households who wish to own a GSAP-Microflush toilet.
6. Closely monitor fabrication of the first 2-3 household toilets.

When the partner organization and GSAP are satisfied that the toilets have been properly fabricated and installed, guidance is offered to the successful new entrepreneur in effective business practice. At 100 units per year (2 per week) and a (conservative) profit of \$50/unit the entrepreneur/craftsman will have her/his income increased by a factor of 2–4. In addition there is a periodic 2–3 year harvesting/dislodging service opportunity of \$20–\$30 per system. The opportunities are enormous: for the entrepreneur, for the community to have a sustainable sanitation solution and for members of the community to share the downstream benefits in education, health and development. Realizing these benefits involves meeting several challenges. The quality of the solution is only as good as the quality of the training. Through the aforementioned pilot application in progress, GSAP has begun a program to produce multiple training resources including: detailed fabrication instructions complemented by sketches, photos and video. A sketch sequence for part of the digester construction is shown in Figure 7.

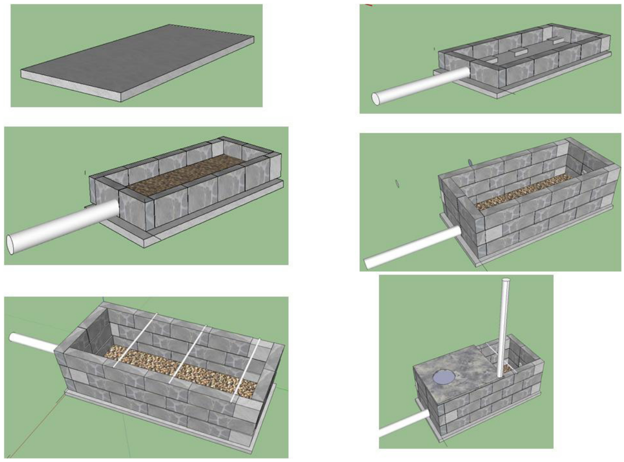

Figure 7: Sketches taken from training guide for on-site fabrication of a GMF digester.

In addition to effective training, even a $300 total system will require access to affordable financing for a household in the target population. GSAP provided funding for the prototype 1H systems and to date there has been 100% payment compliance. Families want and appreciate the dignity and benefits of the GMF toilet. However, traditional financing is expensive (>>30% annual interest rates) and is not accessible to those earning $2-$3 per day. Following the piloting of its training and finance programs, GSAP will be looking to partner with microfinance organizations and secure revolving loan funds in communities around the world to provide sanitation credit for launching its OSF model. The technology being unfolded by the PC-EPS Toilet Group and GSAP [5] is 'open-source' to assure global access in meeting the pressing challenge of providing an effective dignified sanitation solution to the 2.5 billion people who lack access to an effective system [6, 7].

Acknowledgement

The authors are members of the Ghana Sustainable Aid Project (GSAP).

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