

Technical Abstract

The World Health Organisation estimates that 2.6 billion people lack access to improved sanitation, many of whom live in urban informal settlements or 'slums', which are projected to house half of the world's urban population by 2030. Affordable urban sanitation presents a unique set of challenges as the lack of space and resources to construct new latrines makes desludging existing pits necessary and is something that is currently often done manually with significant associated health risks.

There has therefore been a concerted effort to develop mechanised technologies to facilitate pit emptying in high density urban settlements. The majority of these devices use a vacuum to remove material from the top of the pit, however they are typically only able to remove the water-like supernatant fluid. This results in the gradual accumulation of 'unpumpable' sludge in the pit, which eventually fills the latrine, forcing it to be abandoned. The main aim of this project was therefore to develop a method for fluidising 'unpumpable' pit latrine sludge, through a series of laboratory experiments on harmless synthetic sludge.

The first phase of the investigation involved the development of the synthetic sludge and a process for its physical characterisation. Reference data on the physical characteristics of pit latrine sludge were obtained from a study done by the International Reference Centre for Waste Disposal in Botswana during the 1980s. A synthetic sludge consisting of clay and compost was developed to replicate these characteristics. Undrained shear strength and density were identified as the critical parameters controlling 'pumpability'.

It was found that for a given solid composition of sludge, water content correlates strongly with undrained shear strength, and by varying its water content the full range of reported sludge shear strengths could be achieved. The density of the synthetic sludge was found to be significantly lower than that reported by the IRCWD, with a difference in means of around 300kg/m^3 . This is due to the low density of the organic matter in compost, and clay-stabilised soil has been proposed as a possible alternative synthetic sludge with higher density.

It was not possible to determine the effect of solid composition on sludge flow behaviour due to difficulty in controlling water content when different solid compositions were used. The variability in water content of the compost used in the sludge also prevented the development of an absolute 'recipe' for different strengths of sludge and certain amount of experimentation will therefore always be required when developing synthetic sludge from

locally available materials. Nevertheless, the synthetic sludge mixture was deemed suitable to investigate the effect of fluidisation.

The reduction in sludge shear strength from fluidisation was found to be caused by two effects – dilution, which increases water content, and remoulding, which involves mechanical agitation to break down the structure of the material. A one-fifth scale pit emptying device, powered by two modified vacuum cleaners, was used to carry out the fluidisation tests.

The first series of tests was done on a uniform sludge and demonstrated that fluidisation by dilution alone was feasible, however a 23% increase in water content was required to make a strong sludge 'pumpable'. Samples were then left to consolidate before being characterised, producing a material more representative of that found in a pit latrine. Injecting air into these samples produced a three-fold decrease in strength as a result of remoulding at constant water content.

The large increase in water content during fluidisation by dilution causes a large increase in volume which would probably be impractical as there would be insufficient space in the pit. One solution could be to suck weak supernatant off the top of the pit for fluidisation, thereby eliminating the volume increase, however this has associated health risks as the supernatant is heavily contaminated with pathogens. Fortunately this may not be necessary in many cases as air-blown remoulding alone would be sufficient to fluidise all but the strongest of sludges.

The implications for sludge treatment and disposal have been discussed, with the increase in volume and solids content of the sludge removable from the pit potentially encouraging illegal dumping if not managed carefully. It has also been proposed that sludges should be classified according to the equipment required to remove them from the latrine, and possible field tests have been suggested to estimate sludge density and shear strength.

The performance of the equipment used in the laboratory greatly exceeded expectations. This serves as a proof of concept that cheap and easily replaceable vacuum cleaners could be used to replace the expensive vane pumps currently used in most suction-based pit emptying technologies.

Finally, various suggestions have been made for further work, including the development of a synthetic sludge that is more representative of pit latrine sludge and full-scale fluidisation trials using both synthetic and actual pit latrine sludge to validate the findings of this investigation.