Sanitation Extraction & Transport

EPAR Brief No. 131

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March 1, 2011

Introduction

This brief reviews the literature and empirical evidence on waste extraction and treatment in the developing world. The brief assesses the quantity and quality of research supporting key components of program theory related to the extraction of sludge from on-site sanitation facilities and pre-disposal transport. In general, we find few empirical studies that directly evaluate the assertions of the program theory. Most of the evidence in the literature that addresses the target components of program theory is based upon case studies or general observational and experiential assertions by sanitation experts. Where appropriate, we have identified evidence in the literature according to whether case studies or informal observations formed the basis of the conclusion.

Literature Review Methodology

This review was conducted using databases and search engines including: University of Washington Library, EBSCO, Web of Science, Science Direct, Google Scholar, Google, as well as the WHO, UN, UNDP, UNEP, UNICEF, USAID, World Bank, Asian Development Bank, World Toilet Organization, and Water Supply and Sanitation Collaborative Council websites. Searches used combinations of the following terms: collection, content removal, conveyance, decentralized, disposal, dump, dumping, economy(ies) of scale, efficiency, expensive, extraction, extraction business, externality, fecal, faecal, illegal dumping, human waste, illegal disposal, incentive, inexpensive, latrine, low status, market stability, municipal waste, night soil, occupational hazard, on-site, safety, safety equipment, sanitation, septage, septic, septic tank, sewage, sewage removal, sewer, sludge, sludge removal, pit latrine, public health, regulation, removal, removal business, transfer, transfer station, transportation, transportation cost, transport waste, waste removal, waste sludge, waste management. The methodology also included searching for sources that were identified as central works and examining relevant lists of works cited.

Do a Majority of Households, Businesses, and Organizations Rely on Pit Latrines and Septic Tanks?

The most prevalently relied-upon worldwide sanitation statistics, such as those produced by the WHO/UNICEF Joint Monitoring Programme (JMP), do not identify specific types of excreta facilities, but instead report sanitation provision within broader categories of "improved" or "unimproved" sanitation.[1] More detailed JMP statistics on the specific types of sanitation facilities do not appear to be readily available, except at a country-specific level.

Assertions in the literature about the prevalence of specific types of sanitation provision are abundant in spite of the apparent lack of comprehensive worldwide data. For example, Koné (2010) reports that more than 2 billion urban residents in the developing world use on-site sanitation facilities, which he defines to include pit latrines, septic tanks and aqua privies.[2] Much of the literature does conclude that on-plot sanitation is the dominant form of urban sanitation in Africa, Asia and many countries in Latin America, although whether and what data underlie these assertions is not always clear.[3, 4]

Although there is inconsistently reported worldwide data on pit latrine and septic tank prevalence, data on specific types of sanitation facility provision are reported more regularly when the level of focus is a region, country, or metropolitan area. However, self-reported country-specific data may be untrustworthy due to the tendency for developing countries to inflate their true rates of sanitation coverage.[5] Among the statistics encountered in the academic and grey literature:

- Kazmi and Furumai (2005) report that 80% of the urban Asian population uses septic tanks, although it is unclear which data they draw upon for their assertion.[6]
- The Asian Development Bank (2004) examined water supply and sanitation provision in 18 Asian cities. Although the data presented was provided to ADB by the local utilities, they caution that "not all the data are 100% reliable."[7] Across the 18 surveyed cities, an average of 51% of the population had sewerage access; the surveyed cities with the lowest reported percentage of sewerage access were Vientiane (0%), Jakarta (2%), Manila (7%), Ho Chi Minh (12%), Kathmandu (22%), Dhaka (30%) and Colombo (33%).[8] Households not connected to the sewer system are likely to rely on on-site sanitation options including leach pits, septic tanks, bucket latrines and hanging latrines.[9] ADB reports that septic tanks are the most common alternative to sewerage: 30% of Jakarta's population, 37% of Phnom Penh and 70% of Kathmandu are served by communal or individual septic tanks.[10]
- A 2009 survey by the Asian Development Bank of 27 Asian cities in 9 countries found that an average of 47.7% of city populations were served by individual toilets connected to septic tanks, 4.4% by a communal toilet connected to a septic tank, 17.1% by pit latrines, and 17% by open defecation.[11] The report provides exhaustive details on sanitation provision in all 27 surveyed cities.
- Bonu and Kim (2009) examined sanitation provision in India for the Asian Development Bank using data from two national surveys.[12] They determined that as of 2005-2006, 22% of Indians used toilets which flushed to septic tanks, 4.7% used pit latrines of various types, and 55.4% did not have access to any toilet facility and practiced open defecation.[13]
- An empirical study by Gulyani et al. (2010) for the World Bank compared living conditions in slums in Nairobi, Kenya and Dakar, Senegal. Based on data from surveys of 1,755 households in Nairobi and 1,960 households in Dakar, they reported that, 80% of the slum households in Dakar used VIP (ventilated improved pit) latrines or septic tanks, 64% of the population used pit latrines in Nairobi.[14]
- In sub-Saharan Africa, Koné (2010), citing Strauss et al. (2000), asserts that "more than 80% of houses in large cities and up to 100% in secondary towns are served by on-site sanitation facilities," which Koné defines elsewhere in the paper to include latrines, septic tanks, and aqua privies.[15] However the most closely-related statistic to be found in Strauss et al. is an assertion that "depending on the city or town selected, from 65-100% of urban dwellers in Africa and Asia… are served by on-site sanitation systems."[16] Due to the lack of supporting data presented in both Koné and Strauss et al.'s estimates, and the slight inconsistency between the two estimates, these assertions should be interpreted with caution.
- Drawing on unknown data and methodology, the Swiss Federal Institute of Aquatic Science and Technology's (EAWAG) Department of Water and Sanitation in Developing Countries (SANDEC)

(2006) puts the percentage of inhabitants served by on-site sanitation (defined as non-sewered households, public toilets, aqua privies and septic tanks) at 85% in Ghana; over 85% in Tanzania; 98% in Bamako, Mali; 78% in Manila, the Philippines; 98% in rural Philippine towns; and over 50% in Latin America.[17]

- Chaggu et al. (2002) compare numerous studies which estimate the provision of pit latrines in Dar es Salaam, Tanzania at 81-91%, and the provision of septic tanks at 2.5%-17%.[18] Based on data from a national Tanzanian health survey, Chaggu et al. also estimate that 84.6% of households nationwide rely on pit latrines, including 92.6% in urban areas, but that only 1.2% nationwide rely on septic tanks.[19]

What are Prevailing Methods of Emptying Pits and Septic Tanks?

Methods for emptying septic tanks and pits can be broadly categorized as either manual or mechanical in nature.[20] Manual sludge removal is typically accomplished using rudimentary equipment such as buckets, hoes, and shovels. Mechanical emptying can include any number of technologies, but most typically refers to diesel-fueled vacuum pumps connected to storage tanks mounted on trucks. In addition to mechanical and manual emptying, pit latrines may be abandoned once they become too full for use, especially in rural areas where space for a new pit is more readily available than in urban slums.

Manual pit emptying is generally reported to be more expensive on a per-volume basis than mechanized extraction by vacuum tanker.[21,22] Manual emptying is also reported to be slower than mechanized emptying: It may take a manual laborer several days to completely empty a pit.[23,24] However, since manual emptying often provides the flexibility for customers to pay for a partial extraction of pit sludge, it may require smaller lump-sum expenditures on the part of the household at each instance of emptying.[25] Manual extraction may also be the only means of extracting solidified sludge in the lower portions of pits, which vacuum tankers may have trouble removing unless a liquefying process is initiated prior to attempted removal.[26,27,28]

Vacuum tanker trucks are widely reported to be limited in their ability to access latrines in dense urban slums.[29,30] Hoses extending from vacuum pumps are rarely functional beyond a distance of 50 meters, which rules out the option of vacuum-tank sludge removal for many urban latrines.[31] Fuel costs and a shortage of spare parts also hamper vacuum tanker utilization in the developing world.[32,33] Smaller, less expensive mechanized tankers have been developed by a number of organizations, but have encountered various difficulties upon deployment, including slow travel speeds over long distances to disposal sites, and high operational costs.[34,35]

<u>Studies</u>

- Nkansah (2009) and Thye et al. (2009) provide overviews of a variety of small, low-cost vacuum and hand pumps that have been experimentally deployed in the developing world. However, none of these technologies are reported to have yet achieved scalable, sustainable operational success.[36, 37] These technologies include:
    - ASLET (Arian Suction Latrine Emptying Technology), a hand operated diaphragm vacuum pump and cart developed and tried in Afghanistan.
    - BUMI, a hand-operated diaphragm pump deployed experimentally in Zimbabwe.
    - Vacutug, a small mechanical vacuum tanker developed by UN-Habitat and Manus Coffey Associates, and first deployed in Kenya. A second generation Vacutug Model (Vacutug MK II) features a 1,900 liter tank used in conjunction with a 200 liter satellite tank attached to the vacuum pump.[38] Thye et al. (2009) reports that the Vacutug is effective for emptying pits up to

two meters deep. By comparison, traditional vacuum tankers can empty pits two to three meters deep. [39]

- MAPET (Manual Pit-Latrine Emptying Technology), a hand pump and 200 liter vacuum tank mounted on a handcart and designed for use by a three-person team.[40] MAPET was developed by Waste consultants of The Netherlands, and first deployed in Tanzania. Thye et al. (2009) report that MAPET can empty pits up to three meters deep, but also report that MAPET technology has been largely abandoned due to unobtainable spare parts, and a loss of institutional support.[41]
- The Gulper, a small hand pump developed by Steven Sudgen of the London School of Hygiene and Tropical Medicine, and deployed in Tanzania.[42]
- The Manual Desludging Hand Pump (MDHP), developed by the London School of Hygiene and Tropical Medicine and Oxfam, and first deployed in Indonesia.[43] Thye et al. (2009) report that MDHP can empty the top 80cm of pits.[44]
- Larsen Dung Beetles, manufactured in Denmark, and deployed with relative success in Accra, Ghana, according to Boot and Scott (2009). Due to their relatively size, Dung Beetles are adept at emptying bucket latrines, but are still too large to access some of the most densely-populated areas of the city.[45]

- In Accra, Ghana, Boot and Scott (2009) report that vacuum tankers are used to empty the "vast majority" of septic tanks. Most emptying in Accra is performed by approximately 50 private companies. Manual emptying is illegal according to local laws, but a "significant" but unquantifiable number of informal manual extractors operate in spite of the ban.[46] The city's Waste Management Division formerly operated vacuum tankers purchased with international assistance, but most are reported to be broken, and the only tanker reported to be in operation predominately serviced public buildings.[47]
- Parkinson and Quader (2008) report that the majority of on-site sanitation facilities in Dhaka, Bangladesh are emptied manually, in spite of the Bangladeshi government's banning of the practice.[48]
- Koné (2010) references two surveys from 2002 and 2004 which determined that 30-50% of on-site sanitation facilities in West Africa are emptied manually.[49]
- Relying on several un-cited surveys, Klingel's 2001 case study of Nam Dinh, Vietnam reports that only 150 of the city's 35,000 septic tanks were emptied by vacuum tankers in a single year, while an unknown number were emptied manually.[50] He estimated that one third of houses in Nam Dinh are located on streets too narrow to be accessed by vacuum tankers. However, in Haiphong, Vietnam, Klingel reports that almost all houses can be serviced by large vacuum tankers deployed in conjunction with small vacuum tugs and intermediate storage tanks.[51]
- Schaub-Jones (2005) reports that in the five African cities Building Partnerships for Development worked in (Dar es Salaam, Tanzania, Durban, South Africa, Maputo, Mozambique, Maseru, Lethoso, and Nairobi, Kenya), manual pit emptying was "predominant" due to difficult terrain, informal or illegal settlements, and limited tanker access to pits.[52]
- Chaggu et al. (2002) describes two alternative manual pit emptying approaches employed in Dar es Salaam. One method observed involves the gravitational emptying of pits during the rainy season by opening the pit to running rainwater. The second method, called pit "vomiting," involves digging a hole adjacent to the latrine pit and allowing the sludge to flow into the new pit.[53]
- Bongi and Morel (2005), in a case study of Kibera, Kenya, estimate that gravitational emptying is used to empty 13% of pits latrines, mechanical methods are used for 33% of latrines, and manual methods for 28% of latrines.[54] This estimate is based on field interviews with households and service providers.

Expert Assertions Based on Observation and Experience

- The International Red Cross (IRC) and WaterAid estimate that in India, there are as many as 1.5 million "scavengers" whose work entails emptying sludge pits or performing other manual sludge disposal operations. 95% of Indian scavengers are reported to be women.[55] These estimates are based on un-cited data sources.

What are safe methods of emptying pits and septic tanks?

Emptying methods in which sanitation workers do not need to come into physical contact with the sludge are widely assumed to be the safest in terms of minimizing pathogen exposure. In most instances, mechanical emptying techniques allow workers to avoid direct sludge contact, and are therefore concluded to be superior in terms of worker safety.[56,57] Mechanical methods of removal which minimize sludge spillage in public areas also reduce public health risks.[58] We did not encounter any studies which empirically assessed the relative safety of sludge extraction methods.

Studies

- In Dhaka, Bangladesh, Parkinson and Quader (2008) report that the private and public health risks of manual emptying are compounded by the fact that many pit emptiers must work in the dark of night because of the illegal nature of their activities, and get drunk in order to face the smell and filth. These working conditions make them more likely to improperly clean the pits and accidentally spill sludge buckets in areas where public exposure is probable.[59]
- Nkansah (2009), in a case study of sludge management in Tamale, Ghana, noted that fecal sludge from manual emptying was more likely to be dumped within the neighborhood or reused for agriculture, while mechanically emptied sludge had the greatest tendency of being disposed of at the official disposal site.[60] According to the data collected by Nkansah, 36.3% of manually-extracted sludge was buried near the pit site or emptied elsewhere in the neighborhood, while only 11.1% of manually-extracted sludge was officially dumped offsite. By comparison, 93.2% of mechanically extracted sludge was dumped at the official disposal site.[61]

Expert Assertions Based on Observation and Experience

- Anschütz (1997) notes that manual emptying of bucket latrines may present particular hygienic risks because of the breeding environment for insects and pathogens provided by a remaining, post-removal layer of sludge on the bottom of the latrine.[62]

Do Sanitation Extraction and Transport Businesses Fail to Serve Low-Income Communities and Operate in an Unstable Market?

In general, the literature suggests that sludge extraction and removal businesses which rely upon mechanical vacuum and pump equipment may fail to serve low-income communities, which are more likely to depend on manual pit and tank emptying services. In addition to purely economic reasons for not serving low-income communities, mechanical emptying businesses may fail to serve these communities because tanker equipment cannot pass through narrow lanes or up steep hills to reach tucked-away latrines in densely populated urban areas.[63,64] None of the case studies discussed below explicitly base their low-income market-failure assertions on original survey data.

Studies

- Drawing upon five case studies examining private sector involvement in water and sanitation activities in Manila, Abidjan, Buenos Aires, Cordoba and Mexico City, Johnstone et al. (1999) conclude that the higher costs of sanitation provision in poorer neighborhoods, coupled with lower demand from poor customers, will result in private sanitation providers being slow to expand services to poor neighborhoods in the absence of public incentives or regulations.[65] However, this conclusion does not appear to have been statistically confirmed based on data from the case studies, and is not specific to sludge extraction sanitation businesses.
- EAWAG-SANDEC (2006) reports on an un-cited case study in Danang, Vietnam, which observed that six private pit-emptying enterprises charged fees that were unaffordable for many households.[66]
- In Dhaka, Bangladesh, Parkinson and Quader (2008) note that public sanitation services may also fail to serve low-income populations. The official government sanitation service providers, including the Dhaka Water Supply and Sewerage Authority, are not officially permitted to service slums which are unconnected to the city's sewer system.[67]
- Clarke, Menard & Zuluaga (2002) examine the impacts of novel participation by private enterprises in the water and sanitation sector in Guinea. They conclude that private sector participation benefitted all constituents, including consumers, but noted that "it seems plausible… that most of the gains might have accrued to middle- and high-income consumers."[68]

Expert Assertions Based on Observation and Experience

- In Dakar, Senegal, Black and Fawcett (2008) report that the standard US$30 monthly pit emptying fee charged by entrepreneurial sanitation services is unaffordable for poor families.[69] In Durban, South Africa, they note a problem of limited public provision similar to that noted by Parkinson and Quader in Dhaka: A publicly subsidized pit-emptying service costing US$4.50 only extended service to illegal informal settlements during a cholera crisis, and were otherwise unavailable. Private pit-emptying services in Durban were not a viable alternative for poor households due to the US$123 service charge. [70]
- Solo (1999) argues against the prevailing opinion in the literature, asserting that private, independent providers of sanitation services do not fail to reach the poor. She concludes that independent providers of sanitation and water services "appear income and class-blind when it comes to seeking out customers. Their poor customers are clearly willing to pay the prices charged or the providers would be bankrupt." In support of her argument, she notes the profitable operation of a wastewater treatment plant in Cotonou, Benin, one of Africa's poorest countries.[71]

Though we did not encounter studies which directly addressed whether sanitation extraction and transport businesses operate in an unstable market, anecdotal evidence in case studies suggests that demand for pit emptying services fluctuate according to the season and the immediate ability of customers to pay. Anschütz (1997) notes that pit emptying may need to occur at intervals stretching anywhere from three months to 15 years, meaning that customer demand for emptying services may be irregular.[72] Bongi and Morel (2005) report that customer demand for pit emptying is particularly high in Kibera, Kenya during the rainy season, as a result of the immediacy of the sanitation concerns raised by overflowing latrines.[73] Kirango and Muller (1997) also report encountering irregular demand for pit latrine emptying in Dar es Salaam, Tanzania.[74] Jeuland, Koné and Strauss (2004) mention the potential benefits of designing regional sludge extraction systems that regularize demand and make efficient use of equipment by averting the existing tendency for "peaks and troughs" in customer demand.[75]

Do Households Only Have Incentive to Pay for the Emptying of On-Site Facilities if Waste Obstructs Service for the User?

Although we did not encounter literature which relied on data to directly discuss the incentive structure underlying household decisions to remove septic tank or pit waste, in practice we found several examples where households were reported to pay for emptying only when service became obstructed. Most of the support for this hypothesized household decision-making incentive is anecdotal in nature.

Studies:

- EAWAG-SANDEC (2006) reports that in Danang, Vietnam, the high costs of entrepreneurial pit and septic tank extraction services lead households to only pay for emptying "when in-house drainage becomes blocked."[76]
- In a case study of Nam Dinh, Vietnam, Klingel (2001) observes that "septic tanks are generally only emptied when they become blocked, and not at regular intervals," although some individuals with financial means chose to periodically empty their tanks in order to prevent blocking.[77] He also notes that in addition to being motivated to pay for sludge extraction when the tank becomes so full that physical service is interrupted, bad odors emanating from the tank may also motivate certain customers to pay for emptying.[78]

Expert Assertions Based on Observation and Experience

- Based on the sanitation experiences of Building Partnerships for Development in Dar es Salaam, Tanzania, Durban, South Africa, Maputo, Mozambique, Maseru, Lesotho and Nairobi, Kenya, Schaub-Jones (2005) notes that poor customers are likely to pay for manual extraction, rather than mechanical extraction, even though manual extraction is more expensive on a per-volume basis. An advantage of manual emptying is that service providers often offer the flexibility to remove small increments of sludge for a fraction of the cost of emptying the whole pit, which allows service for households who cannot afford to have their entire pit emptied at one time. This phenomenon provides evidence that pit emptying is often initiated only at the point of service obstruction for the user, and completed only to the minimal degree necessary to allow continued use of the pit.[79]
- Black and Fawcett (2008) concur with Schaub-Jones in noting that householders may want to pay for only a minimal amount of sludge removal sufficient to resolve their immediate problem.[80] They observe that when mechanical services suck out only a minimal load, the waste that is removed tends to be watery liquid from the top of the pit or tank. This practice produces long-term pit viability problems due to the solidification and silting of the remaining concentrated sludge, which reduces long-term pit capacity.[81]

Does Scheduled, Safe Waste Extraction Provide a Public Health Benefit?

We did not encounter any empirical data or case studies which directly measured whether sludge extraction services provide a public health benefit. However, several experts conclude, with limited supporting evidence presented, that extraction does provide a public health benefit. For example, Black and Fawcett (2008) assert

> The management of excreta… affects the whole community. The public health and development benefits of good sanitation extend beyond the private benefits gained by the individual who chooses a sanitary toilet over open defecation or 'wrap and throw'; this has been the economic case for

subsidy provision for sewerage in the industrialized world, and should apply to on-site sanitation in the developing world, bearing in mind that the on-site facility doubles as a toilet and a sewer, fulfilling both the private waste emission and public waste disposal requirements.[82]

Among others, Jeuland, Koné, and Strauss (2004) also imply the existence of public health benefits from regular sludge extraction services, arguing that local sludge waste management systems should be designed to function in light of the need to empty pits before they become too full to function properly.[83]

Although we did not identify any studies which have specifically examined the public health benefits of pit extraction and transport services, sanitation interventions in general are well-established to produce public health benefits.

- A meta-analysis by Norman et al. (2010) concluded that sanitation interventions which installed sewer connections resulted in a 30% reduction in diarrheal episodes in the targeted community, or up to 60% when starting sanitation conditions were very poor.[84]
- Fewtrell et al. (2005) found that sanitation interventions reduced diarrheal episode frequency by 32%, while Esrey (1991) found that sanitation interventions reduced diarrheal frequency by 22%.[85,86,87]
- In rural Zimbabwe, Root (2001) found that use of a ventilated "Blair" latrine in a given household provided a "protective effect" for the household's nearest neighbors. Among a sub-sample of 65 households, the study found that households whose neighbors used a ventilated toilet experienced about half the number of diarrheal episodes as did those whose nearest neighbors did not.[88] The authors suggest that the protective effect was due to the lowered likelihood of neighborhood children coming into contact with feces in the area surrounding the household with the ventilated latrine.[89]

While direct users of improved sanitation facilities may experience health benefits from sanitation improvements, a study by Barreto et al. (2007) suggests that health benefits accrued to households as a result of sewer coverage in the neighborhood, and was not correlated with individual household connection to the sewer.[90] Please see EPAR Brief #104 for additional general discussion of the public health benefits of sanitation interventions.

Is Public Investment Necessary to Provide Waste Extraction Service at a Level that will Protect Public Health?

The literature is generally supportive of the idea that public investment is necessary to provide sludge extraction services to a degree sufficient to protect public health, although there is disagreement about exactly what policy mechanisms are the appropriate conduits for public involvement.

Studies

- Fawcett and Black (2008) examined the failure of the NGO WASTE-funded MAPET pilot project in Dar es Salaam, Tanzania, although they did not rely on systematic primary data to support their assertions. The pilot project attempted to utilize the MAPET, a manual pumping machine specifically designed for low-cost sludge extraction, as the centerpiece of a self-sustaining pit emptying business. However, the project languished after a period of initial success after the government sewerage authority in Tanzania was dissolved during the privatization of water and sewer services. As a result, Fawcett and Black reach a general conclusion that "while the household can be expected to install the toilet, and meet

some or all of the pit-emptying costs, the water and sewerage authorities will have to provide the means for transport to the sewage plant for treatment and for final disposal of the sludge."[91]

- Allen et al. (2006) briefly examined sewage extraction provision in Cairo, Egypt, and reported that expensive private extraction businesses were in market competition with less expensive services offered by public emptying vehicles. However, because the public emptying vehicles operated infrequently, sewage commonly overflowed from household tanks.[92] The authors did not cite data to support the suggested causality linking the under-provision of sludge extraction to the overflowing of pits and tanks.
- Hoehn and Krieger (2000) study the correction of wastewater exposure externalities as the result of the implementation of a large-scale sewerage project in Cairo, Egypt which successfully remedied a problem of storage tank overflows in non-sewered areas.[93] Although this study examined the impact of sewerage systems, it does provide an example of government intervention being necessary to correct a negative externality caused by the under-provision of waste extraction services. Even though downstream benefits caused by wastewater treatment could not be measured in the study due to inadequate data, the authors reported that local conveyance benefits, calculated based on household's willingness to pay (a proxy measure necessitated to the fact that the infrastructure project was actually financed by the Egyptian and U.S. Governments), exceeded local conveyance costs by a ratio of 1.2 using a 10% discount rate, and by a ratio of 3.2 using a three percent discount rate.[94]
- A survey by the Asian Development Bank (2009) of sanitation provision in 27 Asian cities reported that only 10% of local utilities do not rely on government funding for capital and operating costs, and instead are able to entirely cover costs through fees and charges.[95]

Expert Assertions Based on Observation and Experience

- Satterthwaite and McGranahan (2006) note that households may have a rational, selfish motivation to prioritize the health benefits of water over those of sanitation because the benefits of safe water accrue to the household while the benefits of sanitation are shared with the community. The existence of the sanitation externality implies a need for public investment or other means of altering the decision-making calculus underlying individual and household defecation behaviors, although the magnitude of the externality to be corrected may be difficult to precisely measure.[96,97,98]

Do Transportation Costs Influence the Dumping of Contents Without Concern for Public Safety?

The literature tends to support the conclusion that transportation costs, among other factors, influence the uncontrolled dumping of sludge by both manual and mechanical pit emptying operations. In addition to transportation costs, several experts mention the disposal fees charged by official transfer stations and treatment sites as a factor influencing uncontrolled sludge dumping.[99,100] Finally, manual pit emptiers may be more likely to dispose of sludge directly into the local environment if manual extraction is outlawed locally, and official disposal options are not available to them.[101,102]

Studies

- Boot and Scott (2009) conducted an analysis of sludge extraction practices in Accra, Ghana, and noted, without referencing supporting data, that sludge disposal fees at official tanker "tipping points" and diesel fuel costs are the two largest expenses for vacuum tank operators.[103] They also assert that reducing haulage distances between households, transfer stations, and eventual disposal and treatment sites could reduce operating costs for vacuum tanker businesses in Accra.[104]

- Mbéguéré et al. (2010) conducted a particularly in-depth analysis of a vacuum tanker business operating in Dakar, Senegal. For the business examined, fuel consumption accounted for 40.1% of annual expenses. Each extraction and disposal trip required an average of 10 liters of diesel fuel, including the fuel required to operate the vacuum pump.[105] This led Mbéguéré et al. to conclude that the business's profitability could be improved
    - By the introduction of more fuel-efficient tankers, or
    - By an extension of the operating hours of disposal and treatment sites, which would allow for tankers to avoid the traffic jams common during the day, and allow the business to be able to make more efficient use of the capital investment in their equipment.[106]

  Beyond direct fuel expenses contributing to transportation costs, an additional 11.3% of total business expenses were allocable to the maintenance and repair of vehicles.[107] Disposal fees at treatment sites, however, only accounted for two percent of expenses.
- Strauss and Montanegro (2002) note that in Kumasi, Ghana, vacuum trunk drivers caught illegally discharging sludge risk losing their license, which may be a contributing factor to the willingness of truck drivers to transport wastes to the official disposal sites and pay discharge fees.[108]
- Jeuland, Koné, and Strauss (2004) report the results of a 2003 study which estimated a 50-100% increase in vehicle maintenance costs, based on unknown methodology, for sludge tank operators as a result of a cessation of indiscriminate dumping and the initiation of disposal at a planned treatment site 17 kilometers from the center of collection in Bamako, Mali.[109] The authors also suggest that if unregulated dumping is allowed to continue to occur after the treatment site opens, entrepreneurs who do choose to use the disposal site will be "less competitive in the free market" due to the costs associated with transport to the site.[110]
- Bongi and Morel (2005), examining sludge disposal in the Nairobi slum of Kibera, Kenya, observe that decisions by manual pit emptiers regarding how to dispose of extracted sludge "primarily depends on the distance of the disposal site from the worksite, as sludge transport is difficult since it is done either by handcart in the best case scenario or carried in buckets."[111] However, they did not cite empirical evidence of this observed decision-making behavior.

<u>Expert Assertions Based on Observation and Experience</u>

- Schaub-Jones (2005) remarks that "the distance between emptying the pit and disposing of the waste is vital to profitability" for sludge extraction businesses.[112]
- Ingallinella et al. (2002), in a general review of fecal sludge management practices in the developing world, observe that vacuum tankers have an incentive to discharge their loads at the shortest possible distance from collection points in order to save time and costs.[113]
- Strauss and Montanegro (2002), two of the co-authors in Ingallinella et al. (2002), again observe that vacuum tankers have an incentive to reduce transport time and costs, and also note that traffic congestion "renders haulage to designated discharge or disposal sites uneconomical and financially unattractive, leading to uncontrolled dumping of collected [fecal sludge] at shortest possible distance from the area of collection."[114]
- Jeuland, Koné, and Strauss (2004), observing the operations of several fecal sludge treatment plants in Western Africa, note that sites which charge businesses to dispose of sludge are generally unable to induce a majority of trucks in operation to use the facility. The exceptions, Kumasi, Ghana, and Dakar, Senegal, feature relatively low disposal fees and strong regulatory enforcement of illegal dumping.[115] Jeuland, Koné, and Strauss also note that the balance of economic incentives encountered by pit

emptying enterprises in determining where to dump tanker sludge are influenced not only by geography and fuel cost considerations, but also by the cultural context in which sludge operations are taking place. For example, the willingness of farmers in Mali to pay for untreated sludge provides a financial incentive for pit-emptying companies to continue unregulated dumping.[116] In other places, such as most of East Africa, where there is less of a market for human fecal waste for farming activities due to Islamic cultural norms, this particular incentive favoring unregulated sludge tank disposal may not be as powerful.[117]

Does the Lack of Public or Private Investment in Transfer Stations and Treatment Sites Factor Into Dumping?

The literature broadly assumes that an undersupply of sludge transfer stations and treatment sites is one cause of uncontrolled dumping, although we did not encounter any empirical evidence underlying this assumption.

Studies

- Parkinson and Quader (2008) report that after the Bangladeshi government banned manual pit emptying, they also closed the Dhaka "trenching grounds" where scavengers had been permitted to dump fecal sludge. As a result, sweepers now dump untreated sludge directly into the city's drainage channels and surface water bodies.[118]
    - Reporting on the implementation of VacuTug extraction service in Dhaka on a trial basis, Parkinson and Quader assert that the lack of disposal points is one of the "main constraints" to service because disposal locations were not always economical or convenient, and local political support for disposal at these waste stations was impermanent.[119] The city's wastewater treatment plant was 15 kilometers away, too far for the VacuTug to travel, and the two other local pumping stations operated by the government were sometimes not easily available. As a result, even though the pilot project was being implemented by WaterAid and the prominent local NGO DSK, VacuTug operators frequently chose to discharge tank contents into local water bodies.[120]

Expert Assertions Based on Observation and Experience

- Schaub-Jones (2005) notes that transfer stations for faecal sludge "rarely exist" in developing countries.[121]
- Ingallinella et al. (2002) remark that the authors "consider the use of semi-centralized (as against centralized) FS [fecal sludge] treatment and neighbourhood septic tanks as particularly expedient… [and] may contribute significantly to reducing indiscriminate dumping of FS."[122] They identify "the diligent siting of an adequate number of FS treatment sites in order to minimize transport mileage and hence indiscriminate dumping of untreated FS" as a fundamental consideration of sludge management.[123]

Do Transfer Stations Improve the Efficiency of Decentralized or On-Site Sanitation Waste Management?

The few case studies that we encountered, as well as the body of expert opinion evident in the literature, support the supposition that transfer stations can improve the efficiency of decentralized fecal sludge management, depending on local conditions.

Studies

- Boot and Scott (2009) state that the installation in Accra, Ghana of underground holding tanks that act as

local, intermediate sludge transfer stations for bucket latrine emptiers has improved the sludge collection system.[124] However, they note that a shortage of vacuum tankers to empty the tanks and remove contents to final disposal sites has led to overflow problems. The authors do not cite data in support of these conclusions.

- Gordon (1999) reports that sludge transfer centers in Accra, Ghana are spatially located in the city such that buckets can be carried by manual pit extractors to the transfer stations.[125]
- Thye et al. (2009) report the results of a 1982 study of sludge disposal in Dar es Salaam, which found that vacuum tankers spent 60% of their time travelling because of the lack of transfer stations in the city.[126]
- By contrast, Klingel (2001) reports that in Nam Dinh, Vietnam, transport distances are short due to the city's layout, and even if all sludge was to be disposed of at a central location outside of the city, the maximum haulage distance would be less than 10 kilometers.[127]
- Parkinson and Quader (2008), observing the VacuTug field trials in Dhaka, Bangladesh, assert that "If there were locations in each neighbourhood throughout the city where faecal waste could be discharged, then the efficiency of operations could be improved significantly because the VacuTug would not need to spend so much time in the congested streets of Dhaka transporting the waste to one of [the local sewer authority]'s pumping stations."[128] They also suggest that government investment in transfer stations or large tanker trucks parked in VacuTug-accessible areas, where waste could then be transported in bulk to treatment facilities, would improve VacuTug waste collection efficiency and efficacy.[129]

Expert Assertions Based on Observation and Experience

- Allen et al. (2006) state that small scale sanitation operations are likely to be viable only if "suitable treatment or transfer facilities are locally available."[130]
- Still (2002) states that the MAPET and VacuTug technologies are not "practical or economical" if the sludge must be disposed of more than one kilometer from the extraction location.[131] Schaub-Jones (2005) reports that MAPET deployment in Tanzania failed partially as a result of the difficulties associated with secondary transport of sludge when local disposal was not an option.[132]
- Perhaps in light of reports such as those by Klingel and Thye et al., which differ regarding the import of transfer stations, Ingallinella et al. (2002) advise that "every city has to be taken at its own merits, given the great variability of spatial settings, sanitation infrastructure and planning mechanisms, which influence sanitation planning and the allocation of suitable sites for either condominial septage tanks or FS treatment plants."[133]

Does Combining Municipal Solid and Human Waste Collection and Transport/Disposal Offer Useful Economies of Scale?

We encountered insufficient discussion in the literature regarding this supposition to either support or question its validity. The only reference we encountered to combining fecal waste collection with other economic activities was in the analysis by Mbéguéré et al. (2010) of a mechanical pit extraction business operating in Dakar, Senegal. Citing a report on septic truck utilization in Sokodé, Togo, Mbéguéré et al. assert that the Dakar business's profitability would be increased "by using multi-purpose trucks capable of carrying various materials like sand, water, gravel."[134] In addition, their financial analysis of the vacuum tanker business in Dakar revealed that the business would be unprofitable if it was not also engaging in other, more profitable activities such as

hydrocarbon emptying and rainwater drainage.[135]

Does the Low Status of Waste Extraction Workers and Low Profit Margins Mean Safety Equipment is Neglected?

There is general agreement in the literature that many waste extraction workers in the developing world, especially those who practice manual extraction, lack basic safety equipment and protective clothing.[136] As a result of the real or perceived unlawfulness of manual pit extraction, these workers often also work under the cover of darkness, which has the potential to compound the hazardousness of the work.[137,138] There is also general agreement in the literature that waste extraction workers are of low social status in many countries, and that there is little social value attached to waste extraction work.[139,140,141] However, we only encountered a few statements that implied the existence of causality between the low-status of waste extraction workers and their lack of safety equipment.

Studies

- Boot and Scott (2009) provide anecdotal evidence of one instance in which basic work safety considerations appear to hold sway: In Accra, Ghana, bucket latrine contractors who utilized unspecified "unsanitary practices" failed to receive operating license renewals.[142]
- Bongi and Morel (2005) report commonplace harassment of manual waste extraction workers in Kibera, Kenya, and state that the work's negative social image obliges the work to be performed at night.[143]
- Kirango and Muller (1997) report a potential reverse causality: The type of equipment utilized by sanitation workers may influence workers' social standing, rather than workers' social standing influencing the equipment that they are provided. In Dar es Salaam, during the trial implementation of the MAPET extraction system, Kirango and Muller reported that workers "gain more public respect because they are using more advanced technology and apply a more hygienic operation… Wearing a MAPET overall uniform and carrying a [waste department] diploma also increases their credibility."[144]
- Anschütz (1997) observes that latrine cleaners are often social or ethnic sub-group, as in India or Pakistan.[145] Van Der Geest (2002) observes a similar phenomenon among ethnic groups employed in sludge collection in West Africa.[146]

Is the Most Expensive Part of Water-Borne Sanitation Systems Conveyance?

Studies

- Hoehn and Krieger (2000) conducted a benefit-cost analysis of a water and sewerage infrastructure improvement program undertaken in Cairo, Egypt. In it, they estimated that the monthly household cost of connection to the sewerage system, including wastewater treatment costs, was US$12.1, versus a $6.3 monthly cost for the household connection alone. Therefore, household connection and waste conveyance was estimated to be about half of the cost of the sewerage system improvement, while treatment comprised the other half of the system's cost.[147]
- Whittington et al. (2009) presented a "rough calculation" estimating the cost components associated with a comprehensive modern water and sewerage infrastructure. They estimated that 40% of total infrastructural costs, a larger portion than any other component, were attributable to wastewater collection and conveyance to a treatment plant.[148]

Are Traditional Water-Borne Sewerage Systems Expensive and Difficult to Maintain, and Does this Relate to the Fact That They are Typically Buried Underground, and Periodically Leak or Break?

In general, the literature appears to support the conclusion that conventional, water-borne sewerage systems are expensive, and that their location underground can exacerbate critical problems and require expensive maintenance solutions.

Studies

- Fenner (2000) describes a finding by UK Water Industry National Assessment of underground sewer assets that a small proportion of incidents can result in a disproportionate amount of repair costs.[149] Fenner reports that many countries have adopted sewer maintenance approaches to reflect a fundamental supposition a critical 20% of the sewer network will cause 80% of the "severe financial, social or ecological problems."[150]
- Paterson et al. (2007) compared several studies which measured the costs of conventional sewerage system construction with the costs of simplified sewerage alternatives. Conventional sewer construction in northeast Brazil was reported to cost US$1,500 per household, and conventional sewerage in rural Jordan was reported to cost US$2,200 per household, while simplified sewerage in Christy Nagar, Pakistan was reported to only cost U.S. $45 per household, US$60 per household in Colombo, Sri Lanka, and US$325 in Natal, Northeast Brazil.[151]
- Hoehn and Krieger (2000) describe that before the initiation of a round of capital funding in the late 1970s dedicated to upgrading and maintaining Cairo, Egypt's sewer system, sewage spills were frequent and disruptive events caused by broken sewer pumps and pipes.[152]
- Esrey et al. (2001) cites an estimate by Cosgrove and Rijsberman (2000) that the annual worldwide investment in conventional water and sewerage is $30 billion, increase to US$75 billion by 2025.[153]

Do Investment Programs Often Lack Funding for Households or Institutions to Connect to the Sewer System, and Require Large Lump Sum Costs that Many Cannot Pay?

There appears to be a general agreement in the literature that sewer connnection costs are unaffordable for the poorest segments of society. However, we did not encounter a prevailing opinion in the literature regarding whether investment programs typically fail to allocate funding to reduce connection costs.

- As early as the 1970s, the World Bank began moving away from traditional sewerage and treatment systems after a two-year study of Bank sanitation investments concluded that sewerage projects were "missing the neediest elements of the society."[154]
- Esrey et al. (2001) note that the costs of pre-treating water used for flushing excreta should be factored into the costs associated with traditional sewer systems.[155] They conclude that due to water resource scarcity in many developing countries, "it is ill-advised to use 15,000 litres of treated and safe drinking water per person every year to flush away an annual per capita output of 35 kilograms of faeces and 500 litres of urine."[156]
- The Asian Development Bank (2004) surveyed and collected data from water and sewer utilities in 18 large Asian cities, and found that the average fee charged by the utilities was US$12 for a household to connect to the utility, although it was unclear if this connection fee was for water alone or for water and sewerage.[157]

The rates charged by utilities were extremely variable, with connection in a several surveyed cities costing over US$100 per household.

Expert Assertions Based on Observation and Experience

- Paterson et al. (2007) describe conventional sewerage systems as "implicitly anti-poor" because cost and water requirements render it unaffordable for low-income communities.[158] They assert that even if communities are willing to pay for sanitation services, "it is often difficult to obtain the initial capital required without access to suitable banking institutions."[159]

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