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Water Impact Statement

This paper considers the socio-political factors that caused an innovative application of a vacuum sewer in an informal settlement to fail. In light of competing demands and rationales in South African service provision, it argues that conflict mediators are needed to work alongside sanitation professionals to effectively address politicisation in multi-objective projects.

Environmental Science: Water Research & Technology

ARTICLE

How sociopolitical factors affected the implementation of Cape Town's vacuum sewer

Lina Taing

Installed in an informal settlement, South Africa's first vacuum sewer failed immediately after its commissioning. Dissent from municipal officials and residents alike collectively contributed to the system's dysfunction. The failed vacuum sewer is emblematic of the limitations of technology-driven approaches in informal settlements, as well as the fallibility of popular policy assumptions about integrated planning and collective community management. It highlights the need to apply multidisciplinary approaches in sanitation delivery, whereby the often-conflicting political aspects of development are confronted in order to provide and sustain basic services in informal settlements.

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Introduction

South Africa's democratic government has prioritised access to basic services since its establishment in 1994.[1] Concerned that affordability restricted access, national policymakers pledged to provide a limited amount of free water, sanitation, refuse removal and electrical services to poor households in January 2001.[2] They notably did not set precise specifications for free water and sanitation, in recognition that implementation should be based upon their municipal counterparts' available resources and local contexts.[3,4] They did, however, suggest that densely populated informal settlements should receive waterborne sewerage. End-users prefer this technology, and it is ideal for draining contaminated water[i] that would otherwise be discarded into stormwater drains and natural water bodies.

Installing conventional gravity sewerage in Cape Town's informal settlements though has proven to be difficult due to various social, built and natural environment challenges.[5,6] Residents generally demand that the government provide sewerage where they already reside, and often refuse to relocate (even temporarily) for construction, for fear of losing their homes. These settlements also tend to be densely structured and situated in low-lying, flood-prone sand dunes near wetlands.[7] The physical restrictions and natural ground conditions make the *in-situ* construction of conventional sewerage problematic, because trenches would need to be dug several metres deep in between closely packed dwellings and into sandy soils with high water tables.

In spite of these challenges, residents have continued to demand flush toilets in informal settlements.[8,9] Officials of the City of Cape Town (CoCT) hence explored alternative technologies that could potentially be applied at scale throughout the municipality. After being assured of its robustness, officials hailed vacuum sewerage as an innovative solution for areas that are difficult to conventionally sewer, and secured funding to construct a vacuum system in one of its most populous and densest informal settlements.[10]

South Africa's first vacuum sewer, however, failed immediately after its commissioning in early 2009. Informal settlement residents consequently demanded that the City remove the flush toilets they had once anticipated, and bring back their buckets.[11] How did this promising endeavour, which had political and financial support, fail?

In this paper, the factors that collectively led to the vacuum sewer's failure are reviewed. The system installed in an informal settlement called Kosovo is described and its operational problems are noted. The roots from which these problems stem are explored, reflecting upon the initial programmatic constraints and assumptions that ultimately contributed to the sewer's dysfunction. Background data was obtained from a document review to explain the City's then motivation for the installation and decisions guiding its implementation. This data was supplemented with observations of and reflections from residents, municipal officials and municipal contractors. The failure of Kosovo's vacuum sewer demonstrates the limitations of a technology-driven approach to sanitation delivery. It further highlights the

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[i] This includes greywater, which comprises the largest fraction of contaminated water from informal settlements.[45,46]

challenge of executing groundbreaking informal settlement interventions in light of conflicting perspectives in project planning.

Methods

A range of qualitative methods in a multiphase longitudinal study were used to understand the research question.[12] The data largely emanated from: (a) a review of documents in municipal project files and university research outputs,[13,14] and (b) the insight gained as a participant observer at CoCT offices and Kosovo informal settlement.

A participant observer is to take part in their research subjects' activities on a day-to-day basis as an insider, and objectively reflect upon emerging social patterns and theories as an outsider.[15,16] I was a participant observer in three CoCT offices for approximately nine months during the period of March 2010 to September 2012. That status follows from having obtained permission to undertake research in and amongst municipal staff for a study on alternative sewerage applications in South Africa. I worked alongside officials as an intern in the informal settlement units of the Water and Sanitation (W&S) Department and Housing Directorate. I was originally situated in the former, and used a snowball technique[ii,17] to migrate to two departments in the latter. For this case study, the experiences and opinions of the following were considered:

- 13 officials from the W&S Department (3 senior officials and 10 officials responsible for project management, O&M and administration of informal settlement water services); and
- 11 officials from the Housing Directorate (7 staff from Development Services, and 4 from the Housing: Informal Settlements unit).

My eight-hour days at municipal offices generally consisted of shadowing officials with backgrounds in engineering or plumbing in their daily tasks—which included new infrastructure assessments; executive management meetings; and site visits to meet with community leaders and monitor on-going projects. As an intern, I specially supported officials in departments that were interested in rehabilitating a dysfunctional vacuum sewer in Kosovo informal settlement by monitoring operation and maintenance (O&M) procedures, preparing internal reports about its status and coordinating an inter-departmental project to salvage the system. Semi-structured interviews were conducted and photographs were taken in Kosovo to understand sanitation conditions in the settlement. This immersive experience enabled me to grasp pressures—such as the social dynamics of everyday office and settlement activities—that compelled or constrained service delivery. I moreover discerned how personal and vocational politics could influence decision-making (individual and collective) and actions in informal settlement servicing.

Ethical approval was received from the University of Cape Town (UCT) to conduct fieldwork. Given the nature of the research, it was not feasible to secure written consent from everyone. Though a consent form was initially prepared, it was eventually treated as an information sheet that introduced the study aims and corroborated the university association. In lieu of written consent, secured verbal consent was generally secured from subjects who were made aware of my identity and study aims either through a mutual acquaintance's introduction or a brief explanation from me, and specified that I could be asked to leave at any time.

No person is referred to by name in order to preserve their anonymity. Triangulated data was gathered from a range of sources (e.g. observation data with information from internal memos and e-mail correspondences with municipal officials and their contractors) to generate reasonable explanations of the factors that eventually contributed to the vacuum sewer's collapse. What follows is a description of the technical aspects of vacuum sewerage and the events and conflicts that influenced the implementation of Kosovo's system.

Vacuum system and failure

The first vacuum sewer was installed in the Netherlands in 1866.[18] Since then, vacuum systems have been widely applied in the commercial sector, such as in airplanes,[19] and over a thousand municipal developments around the globe.[20] Vacuum sewers differ from conventional gravity-reliant systems because they largely use differential air pressure to move waste.[21] Both conventional and vacuum systems initially drain waste away from toilets via gravity. Waste in a conventional sewer then is conveyed off-site by gravity or pumped to a treatment works. A vacuum sewer, on the other hand, stores it on-site in the sump of a collection chamber. The collection chamber contains a pneumatically activated sensor unit[22] in which waste is propelled through an interface valve at a high velocity from the sump towards the vacuum station, and retained in a collection vessel before being conveyed to a treatment facility via a tanker or sewer collection main.[22,23] The differential pressure in the airtight network is generated from pumps at the vacuum station.[20]

In general, wastewater engineers regard vacuum sewers as a last resort for sewering difficult terrains,[21] mostly due to their high capital and operations costs. Vacuum sewers, however, might be more cost-effective when hard rock, flat terrain, unstable soils or high water tables constrict

[ii] Snowballing is a type of sampling in which research participants assist with identifying and recruiting other potential subjects.

construction, as pipes are generally laid at a shallow average depth of 1.5-metres.[20,23] A conventional sewer in such ground conditions would require expensive and difficult to dig deep trenches, as well as a number of pumping stations.[20] The use of vacuum sewers in these scenarios could thus translate into considerable reductions in excavation and machinery costs. Notwithstanding these cost and technical advantages, vacuum sewers remain relatively unknown to sector professionals in Southern Africa.[20] This could potentially translate into: sub-standard contract specifications; inferior construction; and the

Figure 1: Clockwise from the top: (a) A collection chamber in Kosovo's vacuum system, with the sump on the left and the sensor unit on the right (Taing, 15 April 2011); (b) a damaged interface valve diaphragm (Cornelius, 26 June 2009); (c) a brick in the sump (Cornelius, 28 February 2010); and (d) a flooded chamber (Taing, 7 June 2010).

need for outsourcing O&M until operators developed the capacity to manage the system.[20]

In light of Kosovo's natural and built environment challenges, officials concluded that a vacuum system was the only feasible way they could retrofit a sewer in the informal settlement. Kosovo's vacuum system comprised: 354 full-flush toilets grouped together in 42 clusters throughout the settlement; a tap with a concrete basin and collection chamber for each cluster; and a vacuum station.[22] Each cluster had six to fourteen toilets, and waste was conveyed via gravity to a 40ℓ sump in the collection chamber (Figure 1a). The City housed the chambers in pre-cast concrete rings with lockable lids as a security precaution. Officials explained that this feature was added to protect the collection chambers from tampering.

These concrete barriers, however, ultimately exacerbated the sewer's operational problems after the collection chambers malfunctioned shortly after the system's commissioning.[22] The chambers failed because: the interface valves either remained open or shut after sharp items damaged them; and bulky objects caused sump blockages (Figure 1b/c).[22] Wastewater thereafter accumulated in the concrete rings, which contained most of the sewage and flooded the collection chambers as a result. Dirt and fats then clogged the sensor controllers' pilot tubes, which caused them to also malfunction. Air leakages additionally overworked the vacuum station. Sewage subsequently collected between the toilets and the collection chambers because of these operational issues (Figure 1d), and seeped from the system into the surrounding environs (Figure 2a).

After the system malfunctioned, W&S officials shut down the vacuum station, and a municipal contractor de-sludged the collection chambers thrice weekly so residents could continue to use the toilets. Put differently, Kosovo's vacuum sewer essentially functioned as a series of septic tanks that were emptied three times a week. Operating the vacuum sewer as a septic system was impractical, because the 40ℓ sumps had less capacity than other municipal options (namely, 100ℓ un-sewered container toilets; Figure 2b) and overflowed after several flushes. It, moreover, was not cost-effective, for the vacuum-septic toilets' regular de-sludging cost the City up to 18 times more to service than Kosovo's containerised options.[24]

Dissatisfied with the system, residents padlocked toilet doors and disconnected the water supplies, to prevent people from using them (Figure 2c/e). A cluster was also destroyed (Figure 2d). Residents eventually demanded that the City replace the vacuum sewer with a gravity system and, in the interim, safely contain waste in the generally detested but effective container toilets.[11]

The vacuum sewer's failure and the subsequent pollution of its surroundings illustrated, as policymakers had once noted, that a 'complicated, expensive system which is poorly maintained can be just as harmful to the environment as having no system at all.'[25] Yet the CoCT engineers and plumbers responsible for planning and managing the vacuum sewer were no strangers to the significance of infrastructural O&M, as they each had supported the implementation or management of municipal infrastructure for decades. Why then was the vacuum system's O&M problematic? The next sections discuss how dissent throughout the planning and management stages of the sewer's implementation contributed to its breakdown.

Unresolved differences in service provision

It is significant to note that service delivery in Cape Town largely follows the national government's incremental approach to extending basic sanitation access in stages. The stage approach rationally divides roles and responsibilities amongst the following actors in a broadly framed process:

- National policymakers formulate policies and cross-subsidise the capital costs of *Free Basic Services*;
- Municipalities implement these policies in light of their resources and contexts, cross-subsidise the O&M costs of free services, consult with beneficiaries as to the provision of their future services, and maintain underground infrastructure (e.g. pipes); and
- Residents, as the policy beneficiaries, take ownership of the above-ground infrastructure (i.e. their toilets) once built, and pay for usage beyond their free allocations.[4,26,27]

In line with national guidance, CoCT officials assessed their situation, and concluded that they would aim to provide an un-sewered unit to a set of informal settlement households, who, in turn, would manage their toilet as a community.[28] Political support and innovative thinking enabled the City to provide Kosovo with flush toilets connected to a vacuum system. The following unresolved disputes, however, detrimentally prolonged the vacuum sewer's implementation and affected its functionality:

- Servicing conflicts between two municipal departments over who was responsible (and therefore accountable) for planning, implementing and managing W&S infrastructure in informal settlements. Both departments provided new infrastructure, but Housing also coordinated the delivery of basic services to informal settlements, while W&S was solely responsible for O&M.[29] The former implemented the vacuum sewer as part of a rudimentary upgrade of a package of basic services,[30] and expected the latter to operate and maintain it after installation. Division of responsibilities in this decentralised approach to sanitation delivery follows standard practice at CoCT.[31,32] Then senior officials in the W&S Department, however, opposed the technology selection as being inappropriate for an informal settlement.[33] Despite this objection, the vacuum sewer plans went forward due to support from residents, elected officials and the City's administrative management.

Figure 2: Clockwise from top: (a) sewage seeping from a collection chamber (Taing, 29 November 2010). While (b) container toilets are unsightly and smell, Kosovo residents preferred them to the ineffective vacuum toilets because the contents of the plastic containers did not seep into the surrounding environment. Residents, who were dissatisfied with the malfunctioning system, also (c) cut water supplies of units to deter usage (Taing, 11 November 2010) and (d) destroyed toilets in protest (Pan, 30 May 2010). But, as (e) the photo of a full but disconnected toilet indicates, some nevertheless continued to use the vacuum toilets (Taing, 15 April 2011).

- Representation conflicts between factions in Kosovo, which were largely tied to party politics and appointments to limited job opportunities.[13,34] Individuals, who reportedly were unhappy with the outcomes of the City's negotiations, delayed construction by encouraging other residents to not relocate for new works.[13] Some officials also suspected these dissenters intentionally sabotaged the sewer, by deliberately depositing bulky items—such as bricks (Figure 1c) and blocks of wood—into the collection chambers' sumps via the pre-cast concrete rings.[5]
- O&M conflicts between the city and the community over who was responsible for cleaning and maintaining the newly installed communal toilets. In parallel with national government's rationale,[35] municipal officials were expected to undertake off-site and underground O&M duties, while Kosovo's leadership coordinated on-site tasks of the community-managed toilets with users. Many of Kosovo's 15,000 residents, however, indicated that O&M for the City's public toilets was not their responsibility.

Political pressure within the municipality prompted W&S officials to undertake O&M responsibilities in late 2009, with the department's informal settlements unit managing the pipes while its pump station operators maintained the pumps. Pipes officials said they used a trial-and-error approach to operate the vacuum sewer from 2009 to 2011 because they neither received training nor an operations manual to manage it. They, moreover, struggled to work with their pumps counterparts, with both parties reluctant to take responsibility for the collection chambers that technically were neither pipes nor pumps. Lastly, they struggled to coordinate on-the-ground management with Kosovo's wide body of toilet users. The inability to overcome these O&M challenges prompted the City to de-commission the vacuum sewer after three years of operation.

In the end, it was unclear to what degree the vacuum sewer's technical failure was due to poor planning and O&M, inappropriate use and possible sabotage. In hindsight, Cape Town's vacuum system nevertheless was bound to fail due to a diverse range of unresolved institutional and socio-political conflicts that constrained the development of a workable O&M plan for the new sewer. These unsettled differences within and between the divided city and community collectively contributed to major servicing blockages for Kosovo informal settlement, and would likely leave a rehabilitated vacuum system vulnerable to a similar fate.

Such politics in sanitation servicing for informal settlements is not exclusive to Kosovo.[36,37] It also is not unique to Cape Town, for integrated development planning amongst actors with different rationales is a major challenge across the country.[38–42] This suggests that unsettled differences in stage approaches constrain South Africa's development and needs to be urgently addressed if there is to be progress in the country's third decade of democracy. In particular, further research on the political economy of decision-making and effective community engagement methods are important in sanitation delivery, for engineers leading the sector seem reluctant to engage with what they claim to be the irrational politicisation of what should be technically driven services.[5,32]

Conclusions

In March 2016, South Africa's Department of Water and Sanitation (DWS) released its *Draft National Sanitation Policy* for public comment.[43] It largely reinforced the previous positions made in policies that informed the last 22 years of service provision,[4,26,27,35,44] by highlighting the on-going need for:

- Identifying and implementing appropriate sanitation technologies to increase basic coverage;
- Integrated planning of sanitation amongst fragmented and uncoordinated government institutions;
- Pursuing labour-intensive sanitation provision for informal settlements, by employing local residents to assist with construction and community-based operation and maintenance; and
- Setting-up cooperative arrangements for informal settlement sanitation operations, through participatory planning and ensuring that daily basic needs of end-users are met by means of collective management.

DWS has indicated that it will release further guidance on all of the above in the coming year. To encourage and promote change, the government should adopt a multi-disciplinary approach whereby engineers, public health professionals, socio-economic development specialists and informal settlement residents work alongside experienced conflict mediators to overcome dissent in servicing projects.

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References

1 RSA, *The Reconstruction and Development Programme (RDP): A Policy Framework*, Republic of South Africa, 1994, Available from: http://www.gov.za/sites/www.gov.za/files/governmentgazetteid16085.pdf (accessed 6 January 2015).

2 T. Mosdell, in *Democracy and Delivery: Urban policy in South Africa*, Human Sciences Research Council, Cape Town, 2006, pp. 283–301.

3 M. Muller, *Environ. Urban*, 2008, **20**, 67–87.
4 DWAF, *Strategic Framework for Water Services: Water is Life, Sanitation is Dignity*, Department of Water Affairs and Forestry, Pretoria, 2003, Available from: http://www.dwaf.gov.za/Documents/Policies/Strategic Framework approved.pdf (accessed 1 February 2010).
5 L. Taing, N. Armitage, N. Ashipala and A. Spiegel, *TIPS for sewering informal settlements: Technology, Institutions, People and Services*, WRC Report No. TT 557/13, Water Research Commission, Pretoria, 2013.
6 E. Sonnenberg, Toilet provision, Cape Times, 1 Oct 2013.
7 S. M. A. Adelana and Y. Xu, in *Groundwater Pollution in Africa*, eds. Y. Xu and B. Usher, Leiden, 2006, pp. 265–278.
8 PMG, *Bucket System Eradication: Progress Report by DWAF*, Parliamentary Monitoring Group, Cape Town, 2007.
9 S. Robins, Politicisation of human waste, *Cape Times*, 27 Sept 2013.
10 CoCT, *City Work. Newsl.*, City of Cape Town, Feb 2006.
11 Daily Sun, Bring back our buckets!, *Dly. Sun*, 16 Sept 2011.
12 J. W. Creswell, *Research design: Qualitative, quantitative and mixed methods approaches*, Sage Publications, Inc., Thousand Oaks & London, 4th edn., 2014.
13 R. Beauclair, Development and Disappointment: An Ethnographic Study of Kosovo Informal Settlement's Water and Sanitation System Upgrade, MA Thesis, University of Cape Town, 2010.
14 N. Ashipala and N. P. Armitage, *Water Sci. Technol.*, 2011, **64**, 1781–1789.
15 G. Guest, E. Namey and M. Mitchell, in *Collecting Qualitative Data: A Field Manual for Applied Research*, SAGE Publications, Inc., Thousand Oaks, 2014, pp. 75–112.
16 D. McNabb, *Research Methods in Public Administration and Nonprofit Management*, New York, 2nd edn., 2008.
17 V. Jupp, *The SAGE Dictionary of Social Research Methods*, Sage Publications, Inc., London and Thousand Oaks, 1st edn., 2006.
18 E. Petrešin and M. Nekrep, in *34th International Symposium: Water Supply and Drainage for Buildings*, International Council for Research and Innovation in Building and Construction, Rotterdam, 2008, 472–479.
19 US Patent, *Reticulating toilet system for use in aircraft or the like (Inventor: James M. Kemper)*, 1975.
20 C. J. Little, *Water SA*, 2004, **30**, 685–692.
21 S. Van Vuuren and M. Van Dijk, *Waterborne Sanitation Design Guide*, Water Research Commission, Pretoria, 2011.
22 N. Ashipala, The implementation of alternative sewerage in the informal settlements of South Africa, MEng Thesis, University of Cape Town, 2011.
23 EPA, *Alternative Wastewater Collection Systems Manual*, Environmental Protection Agency, Washington, DC, 1991.
24 M. Jooste, personal communication.
25 RSA, *National Sanitation Policy White Paper*, Republic of South Africa: National Sanitation Task Team, Pretoria, 1996, Available from: http://www.dwaf.gov.za/Documents/Policies/National Sanitation Policy.pdf (accessed 20 March 2010).
26 DWAF, *Water Supply and Sanitation Policy White Paper*, Department of Water Affairs and Forestry, Pretoria, 1994, Available from: http://www.dwaf.gov.za/Documents/Policies/WSSP.pdf (accessed 1 February 2010).
27 DWAF, *White Paper on Basic Household Sanitation*, Department of Water Affairs and Forestry, Pretoria, 2001, Available from: http://www.dwaf.gov.za/Documents/Policies/WSSP.pdf (accessed 1 February 2010).
28 CoCT, *Water Services Development Plan*, City of Cape Town, Cape Town, 2001.
29 CoCT, Internal e-mail chain between Development Support, W&S and Housing officials, 13-19 Oct 2005.
30 CoCT, Municipal Infrastructure Grant Project Reg. Form – Kosovo's sanitation upgrade, Cape Town, 2005.
31 N. Graham, Informal settlement upgrading in Cape Town: Challenges, constraints and contradictions within local government, MLitt Thesis, University of Oxford, 2005.
32 L. Taing, Implementing sanitation for informal settlements: Conflicting rationalities in South Africa, PhD Thesis, University of Cape Town, 2015.
33 CoCT, Internal report to City Manager (Botswana Case Study), Cape Town, 2006.
34 CoCT, Mayor to receive memorandum from Kosovo community, Media release, Cape Town, 28 Mar 2006.
35 DWAF, *Free Basic Sanitation Implementation Strategy*, Department of Water Affairs and Forestry, Pretoria, 2008, Available from: https://www.dwaf.gov.za/dir_ws/wspd/policyinfo.aspx?filen=556 (accessed 1 February 2010).
36 S. M. Pan, N. P. Armitage and M. B. Van Ryneveld, *Water SA*, 2015, **41**, 222–231.
37 C. Mcfarlane and J. Silver, *Antipode*, 2016, **0**, 1–24.
38 D. M. Mello and M. H. Maserumule, *J. Public Adm.*, 2010, **45**, 283–294.
39 V. Watson, *Plan. Theory Pract.*, 2003, **4**, 395–407.
40 S. Charlton, *Dev. South. Afr.*, 2009, **26**, 301–315.
41 T. Winkler, *J. Plan. Educ. Res.*, 2013, **33**, 215–227.
42 R. De Satgé, Ways of seeing: Conflicting rationalities in contested urban space - the N2 Gateway in the context of Langa, PhD Thesis, University of Cape Town, 2014.
43 DWS, *Draft National Sanitation Policy*, Department of Water and Sanitation, Pretoria, 2016, Available from: http://www.gov.za/documents/national-sanitation-policy-draft-12-feb-2016-0000 (accessed 14 February 2016).
44 Taing, *Environ. Urban.*, 2017, **6**, 1–16.
45 R. Holden, in *Proceedings of WISA 2010 Biennial Conference and Exhibition: A time to reflect*, Water Institute of South Africa, Durban, 2010.
46 K. Carden, N. Armitage, K. Winter, O. Sichone and U. Rivett, *Urban Water J.*, 2008, **5**, 329–343.