

Toxic remains: Infrastructural failure in a Ugandan molecular biology lab

Social Studies of Science
2021, Vol. 51(5) 707–728

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DOI: 10.1177/03063127211011531

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Abstract

This article complicates romances of infrastructural improvisation by describing infrastructural failures that expose researchers to hazardous chemicals in a Ugandan molecular biology lab. To meet project deadlines, to make careers and to participate in transnational collaborative projects, Ugandan biologists have to stand in for decaying or absent infrastructures with their bodies. Ugandan biologists hide such sacrifices from their international scientific partners and direct the blame elsewhere. An unclear culpability results precisely from the ways in which power works and is distributed across transnational scientific infrastructures.

Keywords

toxicity, infrastructure, postcolonial technoscience, molecular biology, Uganda

I almost bumped into Dr Jimmy Tindamanyire¹ in June 2017 as he was hastening in large, angry strides out of the lab front door. A talented postdoc, he had just returned to this Ugandan laboratory from Brisbane, Australia, where he had completed his PhD at Queensland University of Technology (QUT). In his left hand was a tray with small test tubes; in his right, a square plastic container with several bottles of chemicals. ‘Oh God, this place is killing me!’, he aired in frustration: ‘You spend all day running after stuff and don’t even get to doing the real work!’ Standing in the doorway of the lab building, beside the guard dozing on a chair, Dr Tindamanyire sighed and explained that he had again failed to make the buffer needed for a procedure (the buffer is a chemical solution that keeps the pH value stable in samples). The first time he tried to make it, the chemicals had expired and the buffer failed to work. This time the machine to distill water had

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broken down in the tissue-culture building next door, and he hadn't known that the water he used couldn't be trusted. No one had told him and there was no sign. So, he made a second useless buffer that even had dirt particles swimming in it. He would have to try a third time from scratch until he was able to make the right buffer, chasing after equipment and chemicals. It took him days to finish a simple task that takes an hour or less at the well-organized QUT labs where he did his PhD.

Infrastructure should work efficiently, unnoticeable in the background, so one can get on with the really important things – 'the real work', as Dr Tindamanyire called it. The practice of molecular biology requires a functioning research infrastructure, including lab space, up-to-date technologies, chemicals, skilled staff and research protocols. It has become a scholarly commonplace that such infrastructure is usually taken for granted and backgrounded until it fails to deliver, breaks down and denies participation in the practice it was meant to support.²

Star and Ruhleder (1996: 113) identify breakdown as a central moment for scholars of infrastructure by asserting that it makes its taken-for-granted dimensions visible. Their work stimulated more scholarly interest in the off-script and often unacknowledged labors of repair, maintenance, improvisation and tinkering required to sustain any high-tech practice.³ For example, Orr's (1996) ethnography of technicians repairing photocopiers for US companies highlights technicians' skilled improvisations and their 'propensity to tinker' (p. 66) as they have been tasked to maintain the technological infrastructure for others. Orr observes that there often is an opening to display heroism, whereby the technician-hero comes to the rescue and fixes the problem (p. 160) – this heroism of repair work was an ethos Orr's interlocutors embraced.

Some recent literature on infrastructure in the Global South also paints a heroic picture of tinkering and improvisation, of those moments where people have to creatively adapt, fix or mend infrastructure to keep things going. Responses to material deprivation can take the form of a David-versus-Goliath story, where excluded slum or township dwellers in places like Mumbai, Johannesburg or Delhi creatively tinker with electricity or water meters to avoid user fees or gain illegal access to electricity and pumped water (Anand, 2011; Gupta, 2015: 560–562; Von Schnitzler, 2013). To account for such improvisations, Simone (2004) argues for a need to extend our conception of infrastructure to include 'people as infrastructure'.⁴ By this, he means that social relationships can be used to provisionally bridge gaps of infrastructure, like the informal networks of those excluded from public infrastructures in Johannesburg. These are also important themes in scholarship on biomedical practice in the Global South, though these accounts, because of the often fatal consequences of improvisation, tend to be less celebratory.⁵

It is undeniably important to highlight the creativity and agency of people who, lacking resources, have to make do and stitch fraying infrastructures together. This holds true especially in African settings, where people still are far too often portrayed as largely victims of world historical processes. Hence, highlighting creative and subversive tinkering with infrastructures is also a way of writing against pervasive tropes of dysfunction, neglect and decline in the Global South (Wainaina, 2005). And yet, at times this important correction of ways of writing about Africa has fed its opposite – a romance of improvisation, of repair, recycling and reuse that backgrounds the darker side, the humiliation and the dangers that can also be lurking when people step into infrastructural gaps.⁶

Infrastructural breakdown anywhere in the world indexes and simultaneously perpetuates inequalities (Howe et al., 2016: 557). While this key STS insight warns of exoticizing infrastructural failure in the Global South, it also shouldn't lead to brushing aside the deep layers of systematic inequality that have accreted over a long time. In the Ugandan research institute where I did nearly fourteen months of ethnographic fieldwork with molecular biologists, infrastructures frequently broke down. There were recurring moments of frustration and humiliation that resulted from performing scientific work in a discontinuous infrastructural palimpsest. Shortages of materials and spare parts forced researchers to stop their work and wait. At other times, machines broke down in the middle of a procedure and exposed researchers to toxic chemicals. To avoid disappointing their overseas scientific partners and to prevent organic materials from degrading, these biologists not only became 'people as infrastructure' (Simone, 2004), creatively mending failing devices with their own means, but also repeatedly stood in with their bodily tissues.

I call this predicament one of 'toxic remains', a mixture of substance and sentiment that Ugandan researchers are left with after transnational research projects are completed. These may be harms absorbed by their bodies, or, in a more metaphorical sense, the harms of anxiety about exposures. This moves the discussion beyond the romance of creative improvisation and African ingenuity. It rather joins accounts that highlight the substances and ideas that seep through the infrastructural cracks and bind laboring bodies to often distant scientific or industrial processes (e.g. Blanchette, 2019; Droney, 2014; Hecht, 2012).

While hinged on infrastructural failure, this story of toxic remains is not mainly about failure, but instead is about the remarkable accomplishments of Ugandan molecular biologists. These are people who embody progress and success in contemporary Uganda; they are respectfully called 'doctor' by other Ugandans. They are part of the country's rising middle class and part of its educated elite; many have traveled abroad. And yet, their successes sometimes demand sacrificing their bodily health and their dignity. Such personal sacrifices are invisible for their international collaborators. This article traces how unequal exposure results from inequalities in transnational scientific infrastructures and details how Ugandan researchers reflect on these differences between their lab at Kawanda and partner labs in the Global North. While material inequalities do not operate behind researchers' backs, the long and unplanned accretion of infrastructural layers still complicates establishing a clear responsibility for harmful exposures.

Layers of research infrastructure

Uganda's National Agricultural Research Laboratories are located on the outskirts of a periurban town called Kawanda, just 12 km north of the capital Kampala. The institute's mission is to develop solutions to problems that Ugandan small farmers are facing, like pests, diseases or diminishing yields. I worked closely with a project that is creating genetically modified (GM) bananas to increase their beta-carotene content and thereby prevent vitamin A deficiency in the Ugandan population. The Gates Foundation has funded this project since 2005 and James Dale at Queensland University of Technology (QUT) in Australia directs it. Fifteen years after the project's inception, Kawanda prides



Figure 1. The biotechnology lab at Kawanda (the old colonial coffee lab), July 27, 2016 (S Calkins).

itself on being the first molecular biology laboratory in Sub-Saharan Africa that has managed to transform a living organism – the banana – in its own laboratories.

The building that today houses the biotech lab was built by British colonizers in 1937 and was the main laboratory for work on coffee (Chenery, 1960: 10), a crop among the so-called ‘colonial primary products’, such as cotton and tea, ultimately destined for export and sale on global markets. The opening up of Uganda for agricultural research and crop development was closely linked to the completion of the Uganda railway in 1901 that connected Jinja in Central Uganda to the Kenyan town of Kisumu (Chenery, 1960: 5). From there, crops could be linked to broader marketing networks that moved them to the port for quick and cheap export. The British led a number of experiments in coffee, cocoa, rubber tea and later cotton, first at the Botanical Garden in Entebbe, then the Kampala plantation, then at the burgeoning experimental stations like the one at Kawanda, Serere or Bukalasa that were equipped with the latest technologies of the time (Figure 1).

The Kawanda lab today is under the auspices of the Ugandan Ministry of Agriculture and receives a small budget, but its research activities are funded through collaborative research projects with partners in the Global North.⁷ To be able to commence work on the vitamin-enriched GM banana at Kawanda, the Australian partners transferred their entire ‘pipeline’ to Uganda. The pipeline is the immediate research infrastructure that

was assembled to carry out the project-specific molecular work, including the scientific protocols, techniques, new fridges, centrifuges and other devices, as well as the training Ugandan researchers received at QUT, but it excludes basic infrastructural services. Dale and his QUT team soon learned that transferring the pipeline ten years ago did not make work in Kawanda as straightforward and easy as they had hoped. Referring to the Global South, Latour (1993: 98) points out that the scientific gaze cannot be established by simply transferring technology, like a microscope, to a new setting. A technology is implicated in infrastructure, and one infrastructure hinges on others: Since there were no reliable power and water infrastructures in place that supported the whole institute in Kawanda, the approach, like those of many other donor-funded projects, could only be piecemeal, Dale admitted with frustration in a conversation in his QUT office – a dilemma to which I will return a bit later.

In spite of infrastructural instabilities, plants, buildings, technologies, protocols, chemicals and skilled labor power do hold together often enough at Kawanda and enable scientists to work. However, there are also moments when these infrastructures fall apart and individual researchers have to step in to hold them together. Much discussion has been devoted to infrastructure as a never-complete work in progress that integrates materials and dreams from different epochs.⁸ This is still an important angle on well-studied sites of African science, such as Kisumu in Kenya, Amani in Tanzania, the Institute Pasteur in Cameroon, the toxicology lab at Université Cheikh Anta Diop in Dakar or – to return to the case at hand – Kawanda in Uganda that have similar histories. In these settings, infrastructures started with colonial foundations, became integral to nationalist state-making on independence, went mostly underfunded and mismanaged in the decades after independence, and more recently invited a proliferation of short-term and narrow well-funded collaborative projects.⁹

At Kawanda too, the historically accreted infrastructural layers often do not cohere with present scientific needs, producing friction and nostalgia.¹⁰ Corroding infrastructures affectively texture scientific work in ways that contrast with an ethos of infinite scientific progress that still shapes Ugandan scientists' expectations (see also Drone, 2014; Tousignant, 2013a: 730–731). At Kawanda, scientists reap successes, but they do so in an overall environment of infrastructural instability and occasional toxic exposure, where infrastructures often leak and confound otherwise easy-to-assume distinctions between infrastructure and its environment as well as between the body's inside and outside (Nading, 2017; Weston, 2017). This becomes clearer when we look at toxic exposures at Kawanda.

Toxic exposures

A big golden sign on the wall next to the entrance to the biotech lab informs that it was inaugurated in 2003 by Uganda's President Yoweri Museveni himself, who aspires to turn his country into the biotech hub of East Africa (see also Harsh et al., 2019). This dream reflects modernist promises of development through the planting of infrastructure, but also postcolonial assertions of African-led scientific progress and self-determination concerning what uses to make of biotechnology. While a lot of money has gone into equipping labs at Kawanda with new technologies, up-to-date devices and well-trained

research personnel with PhDs from abroad, the dreams of progress and modernity, of creating the conditions to practice molecular biology up to the latest standards, still meet material limitations.

‘This is Kawanda!’, was a common sigh of exasperation, a curse hurled against the walls and into the ears of nearby colleagues and myself. I heard this often when power went out, devices collapsed, disposable items like gloves had to be reused or chemicals had to be substituted with inferior or expired solvents. Or, on a number of occasions, I heard it when researchers returned to their work on Monday mornings to find their frozen samples had thawed or that the cell cultures on which they had been working for weeks had been destroyed due to power outages. I also heard this when biologists had to repair the laboratory equipment they needed to continue their work themselves, when missing spare parts were not replaced and when chemicals and other research materials were scarce or out of stock. ‘This is Kawanda!’ indexes the contrast between an identifiable lab, placed in Central Uganda, and the placeless lab that fuels so much of technoscientific imagination (see also Droney, 2014).

But what does this all mean for the practice of molecular biology that relies on the replicability of research protocols and the reproducibility of results? QUT developed and tested what molecular biologists call ‘the technology’, the combination of the gene for insertion and the promoter that initiates its integration into the Ugandan banana’s genome. The protocols outlining the research process had to be applied exactly the same way in Uganda to render valid results. But Anthony, an experienced lab technician at Kawanda, shrewdly put it this way: ‘These Australian things don’t work here’. He was referring to the constant departures from the Australian protocol that were needed to keep the work going and to produce results in a space of infrastructural instability. While celebratory analyses of African ingenuity in adverse circumstances and the unwavering ability to improvise solutions may often be warranted, infrastructural gaps can also worsen inequalities.

To give an example: Much of the manual work in molecular biology is done under fume hoods, small closets where scientists work with toxic chemicals and the chemical vapors are sucked up. The scientist’s head stays outside and only the hands are moved inside; the sliding glass door is let down as far as possible. Dr Stephen Buah, a postdoctoral researcher who had recently arrived from finishing his PhD in Australia when I first did fieldwork in the laboratory in May 2015, set out to extract DNA from banana leaf samples that had previously been processed. Buah didn’t trust the fume hood at Kawanda. It sucked up too little, he found, after testing the strength of the air suction by placing a piece of paper at the slit where he found he could comfortably work. He tested how far down the cover needed to be pulled to prevent him from inhaling chemicals, but then he realized he couldn’t move his hands properly. He had to leave a wider gap open than what he considered safe. ‘Kawanda!’, he sighed, and got to work.

Additionally, a few days later, the light bulb inside of the fume hood burned out, and it would be weeks before a replacement bulb could be secured. Without light in the fume hood, researchers on the team could not see the fine layer of plant DNA in the test tubes that they had to remove by pipette. Under pressure to meet project deadlines and extract the DNA for their Australian partners, who were scheduled to run further tests on them, Dr Okemi, who was working at the fume hood, began to move the tubes out of the hood,



Figure 2. Dr Okemi doing molecular work in the fume hood. Kawanda, June 26, 2015 (S Calkins).

holding them up in the room to be able to tell the DNA apart from other plant tissue while pipetting. On that day they were working on 24 samples. The scientific protocol they followed for DNA extractions involves several rounds of adding chemicals, centrifuging and then pipetting off the upper layers. This meant exposure to chemicals over two to three hours, particularly to the highly toxic beta-mercaptoethanol.

As the small room and our lungs were filling with the stench of this chemical – a weird stinking mixture of burnt plastic and rotten eggs – and several other chemicals such as chloroform and isopropanol – I had to think about the optimism and praise of creativity involved in scholarly accounts of infrastructural improvisation. Here, the ‘tinkering’ involved danger, being exposed to toxic substances and experiencing physical sensations like dizziness, burning, teary eyes and respiratory irritations. Thinking about the bodies of the researchers who work in these polluted surroundings and often complain about headaches and problems with their eyes or noses suggests that this type of muddling through also perpetuates the toxic inequalities of infrastructure and the uneven distributions of risks and benefits that define contemporary global science (Figures 2 and 3).

During my two months of fieldwork on the Australian side of the project in early 2017, I could confirm that no one would have worked under these conditions at QUT; they would be considered an unacceptable violation of work-safety regulations. Even

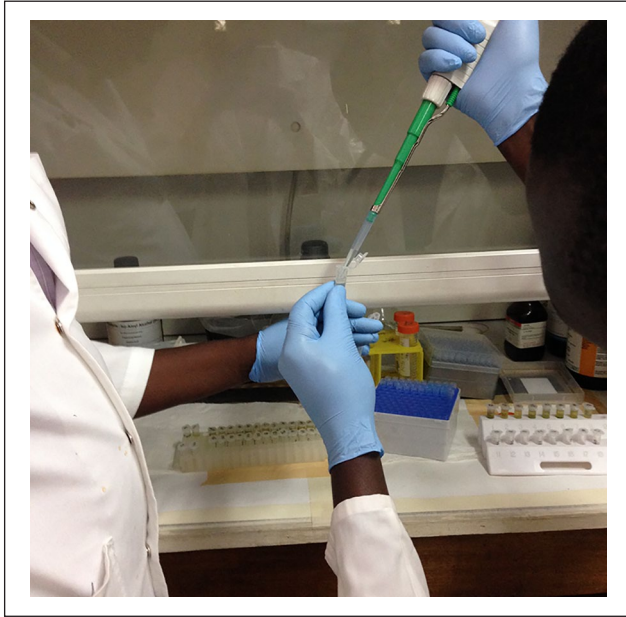


Figure 3. Researchers pipetting off layers from test tubes outside of the fume hood (unsafe). Kawanda, July 9, 2015 (S Calkins).

being able to smell a toxic chemical like beta-mercaptoethanol in the large, white and immaculately clean QUT lab is seen as an incident that has to be reported to supervisors and the lab manager. This is in keeping with strict institutional accountability measures that exist in order to rule out researchers' negligence and to prevent putting oneself and colleagues sharing the lab space at risk. A larger spill of beta-mercaptoethanol, I was told, can cause a lab evacuation. On the Australian side, continuous labor goes into servicing, updating, testing and maintaining the research infrastructure, but it is a labor that can largely be ignored by the scientist and is invisible to them (apart from emails in which the lab manager informs which devices were serviced that I also found in my inbox). It is a type of labor that is efficiently done in the background.

Not so in Uganda. The whole lab in Kawanda is known to be unsafe, stinky and over-exposed to toxic chemicals that have seeped into its equipment, walls and furniture, and which stick to desks, cupboards and door handles. Senior researchers, who had done their PhDs abroad, warned me – the visiting anthropologist who had little clue about the dangers lurking in this lab – on several occasions to try and limit the time I spend in this lab, cautioning 'it's unhealthy' and 'don't overstay here'. Other advice that I never heard repeated to Ugandan staff was to go and breathe fresh air in between sessions, to not only wash my hands thoroughly with soap but my face also. One postdoc, who found me in the lab on several occasions, cautioned that 'you may think it's like a lab at home but it's not safe for you here!' I wondered what he meant by saying it wasn't safe for me. Did he imply unsafe circumstances were just fine for his fellow Ugandans and that my body

should be more protected? I struck up several conversations with this postdoc later and am convinced he meant these words of caution for me as someone who was there voluntarily and who, unlike the Ugandan staff struggling to make a living and work on their careers, could avoid toxic exposures. In his view, I did not have to make such personal sacrifices.

Young researchers at Kawanda speculate anxiously about chemical exposures and whether they might relate to fertility issues that some have been experiencing – having children is still central to achieving full man- and womanhood in Uganda. One young research assistant who delivered a healthy baby was fearful of toxic exposures during her pregnancy and linked a fellow worker's late miscarriage to her overexposure to ethanol in the tissue culture lab. I heard this story several times. However, Anthony contested this conclusion when he overheard a conversation I was having with some of the young scientists. He objected that the cause of her miscarriage couldn't be easily established, as 'it could come from anything. They can't test chemicals for human reproductive toxicity.'

In spite of different individual bodily sensations, Ugandan biologists' experience of toxic exposure is informed by their university education in molecular biology. They have a knowledge of occupational health studies and the ways chemicals are ingested, of the sorts of molecular compounds they can form in one's body and the range of possible reactions and long-term harms different exposures are associated with. Scientists at Kawanda explained to me, without a background in biology or formal lab experience, what harms certain chemicals could cause, what inhaling chloroform or isopropanol could do to my nervous system, how to handle potassium hydroxide with care, how to move my body through contaminated lab spaces to avoid contact with the highly carcinogenic ethidium bromide and so on (Calkins, 2020). Ugandan researchers' knowledge of chemicals is, of course, central to the practice of molecular biology, but it also enables them to reflect on the ethical implications of their experiences.

Ugandan scientists speak about toxicity in order to make sense of harms that have already occurred, like the miscarriage or specific health problems, such as respiratory issues and hurting eyes or heads. They thereby expose a gap between their everyday experiences of working in crumbling research infrastructures and the measures that they know should be in place to protect their own bodies from work-related harms. Yet this is not a toxicology lab, and evidence of chemical exposure is hard to establish without an elaborate and costly apparatus that would allow testing for specific toxic substances (see Hecht, 2012: 40–42; Tousignant, 2018). Murphy's (2006: 6, 7) discussion of the 'sick building syndrome' highlights such problematic uncertainties. She argues that the difficulties in establishing evidence for chemical exposures, a result of 'regimes of imperceptibility', play into the hands of power that is strategically ignorant of exposures. Furthermore, many toxic substances harm in unpredictable and slow ways that exceed the available scientific means of establishing clear causality (Liboiron, 2016: 98; Tironi, 2018). To move beyond the impasse created by lacking evidence of chemical exposure, Shapiro (2015: 369) explores the 'chemical sublime'. This he understands as the small chemical changes that humans can learn to detect by attuning their bodies to their environments – the contention is that the experienced body can serve as a meter. The exposures experienced at Kawanda differ from both Murphy's and Shapiro's cases. Molecular biology routinely employs a variety of chemicals; some more and others less hazardous.

Ugandan researchers know both the substances and the work safety standards and regulations that in principle should ensure their bodily safety but then practically do not.

Ugandan scientists find themselves at the margins of discontinuous corroding infrastructures. Maintaining scientific connectivity in the face of missing or failing infrastructures can entail stepping in and thereby risking a type of molecular connectivity, where researchers' bodies become touched by harmful chemicals and may end up being worn out and damaged. The anxiety around toxic exposures in Kawanda indicates Ugandan scientists' awareness of this precarious 'chemical embodiment' and their experiences of powerlessness as they are bound molecularly to unequal scientific infrastructures that run through their lungs and bodies and expand far beyond Uganda (Murphy, 2008: 696). Beyond the embodied toxic remains, however, there also are toxic remains in a more figurative sense.

The toxicity of decay

'Toxic' here refers not only to chemicals that leak into bodies and the lab environment, but also to the effects produced by working in decaying infrastructural leftovers. Drawing on Fanon's characterization of racism as a poison, Stoler (2008: 193ff) raises the question of how far present human potentials – both real and imagined – are bound to the refuse of imperial formations. She focuses on ruination as a process of material corrosion of the environments in which people live and work, a process that also shapes and degrades people's experience of the world. In Kawanda, the leftovers of colonial science remind researchers of more hopeful pasts and produce a sense of lost capacity that can devalue their experience of the present and their capacity to imagine other futures (Geissler and Tousignant, 2016; Tousignant, 2013a, 2018). It makes sense to think about lingering violence and inequality in many African settings as a toxic force that is both materially and metaphorically disruptive of bodies and senses of futurity (Hoffman, 2017). Toxic remains in such a material and metaphorical sense highlight contradictions that arise from multiple, only partially connected layers of new and old infrastructure and comparisons that Ugandan researchers draw with 'proper science' that is being done elsewhere and that was being done at an earlier time.

Let us return to the piecemeal infrastructure at Kawanda that Dale had mentioned and the lack of reliable power and water infrastructures. To secure the institute's water supply, the British had installed three pumps drawing from underground boreholes in the 1930s. They even kept a staff swimming pool running until the 1960s. Today this is a deserted structure, surrounded by corrugated metal, overtaken by shrubs and plants that grow in it. Since the British left and the experimental stations were taken over by the postcolonial Ugandan government, there were no major investments in replacing corroding water pumps. Only one of three old pumps works today. The large pumping station transports underground water into tanks on a nearby hilltop and distributes the water via gravitational flow; it is run on electricity and only runs in the mornings. When the power is out in the morning, the tanks don't fill and the lab goes without water for the day, and possibly several more. The water pump not only services the institute but also the village that emerged around it, a problem that the British planners never foresaw (Anand, 2017).

Kawanda signifies national development and progress to the Ugandan public. So it was an unexpected sight to encounter Zahara Mbuya, a short and petite scientist, struggling to carry a 20-L jerrycan across the research station, 300m from the soil science building. Zahara¹¹ works in the tissue culture lab, where she is responsible for maintaining cell cultures and backup plant copies alive for the Gates project. But in the tissue culture lab the water is often out. To prevent the loss of cultures and to be able to do her work, she manually fetches water. She said she could more easily carry it on her head but people would ridicule her. 'It's a biotech lab after all and not some village – at least you should think!' She further complained that her friends and family would not believe that she was in fact carrying water like a village child, when she almost had her master's degree. For Zahara, infrastructural failure was personal. It wasn't just that the water pipes eroded, but that as a proper scientist she shouldn't have to think about infrastructure or use her body in demeaning ways, even for a moment, to make it work.

Decaying infrastructures in Kawanda can humiliate researchers. For Zahara, they didn't fit her overall understanding of being a young aspiring scientist, nearly having finished her master's thesis and looking ahead for employment in the life sciences, perhaps even a PhD opportunity. Zahara is ambitious and understands herself as 'serious', as opposed to other young people who refuse to carry water, and just sit around idly playing games or texting on their phones. 'Serious people' like Zahara or Dr Tindamanyire place emphasis on working diligently and planning their next career steps. Resourcefully, they often find a way to continue their work, while some research assistants refuse to let themselves be turned into the edge of infrastructure and justify project delays by the lack of water or missing chemicals. Yet, superiors clearly did not think that refusal was a proper response, and referred to the research assistants who did not stand in for decaying materials as idle, unmotivated and not serious. It was harder for these researchers to move ahead professionally and find employment in another project.

Constant infrastructure issues are concerns through which researchers reflect on their own dignity and assess their relations to the state (Street, 2014: 12). In particular, the corrosion and material decay of the water infrastructure animates explicit critique. Some said the lack of water proved the government's misguided policies and lack of political will; it showed where their priorities were. Zahara complained once in the lab when she tried to open the faucet in vain: 'Eh, how is that we don't have any water again? They should at least harvest rainwater.' 'They' referred to those in charge at Kawanda as well as the Ministry of Agriculture, which provided the budget. Another researcher, who was prowling through the lab on the lookout for pipette tips, noted sarcastically that Zahara had it wrong: Kawanda stood for high-tech solutions for farmers and so of course couldn't be bothered to apply the simplest technologies that even grandmothers in villages have, namely, rainwater tanks. When researchers spoke of 'the village' in Kawanda, it was usually used in a generic way to crystallize ideas of backwardness and superstition, and to set them apart from the institute's mission of science-led progress and development. However, one doesn't have to stroll far from the laboratories to get the impression that the village with which Zahara and others fear being associated extends to Kawanda. Washing lines with bright kids' clothing and the smoke from fires indicate where squatters have occupied former British residential houses. These are mostly decaying structures with broken windows, tiles falling off roofs, barred doors and feral gardens.

What distinguishes the sacrifices Kawanda's biologists make from those that are idealized as the selfless pursuit of 'pure science' is that they result from powerlessness and a 'lack of alternative', not from choice (Herzig, 2005: 48, 118). In her analysis of 19th century science, Herzig (2005: 65) shows that the idea of 'the sacrifice for science' was rooted in liberal notions of selfhood, with the typical racial and sexual exclusions, where only an independent, male and white individual was able to choose to suffer voluntarily for such purportedly noble ends as the love of truth or the progress of science. Following this logic, Ugandan scientists' sacrifices may be hidden precisely because they signal debasement and shame and not voluntary dedication to science.

Ugandan researchers are not only constantly drawing comparisons to other labs like the well-stocked one at QUT, but also compare the present to imaginations of a better, safer and more efficient past, when Kawanda was a key site of knowledge production, when the colonial government invested in infrastructures, when scientific careers could be made and important insights about coffee, cotton and other tropical commodities were gained. The remains of the colonial past at Kawanda materialize the lost possibility of doing world-class science in Uganda. They are reminders of a past state when the lab was on the forefront of British colonial science.

Of course, nostalgia for Kawanda's colonial past is likely heavily idealized. None of the researchers around today experienced the colonial lab, where people were also working with dangerous chemicals, making it hard to argue that the work then was less toxic than today. However, if we think about toxicity both materially and metaphorically as that which is damaged and seems beyond remediation (Hoffman, 2017), then we might say that the colonial lab was indeed less toxic. Even though it was part of an 'evil infrastructure' (Kely, 2017) based on the exploration and subsequent exploitation of the Uganda Protectorate, it successfully transported a sense of opportunity, dreams of the progress and pride in national development that now seem to be unfurling, just like the pipes and cables themselves (Geissler et al., 2016; Tousignant, 2013a).

One researcher concluded in disappointment that there was no interest on the side of the government in installing a working infrastructure, apart from occasional piecemeal repairs. 'Look around you', he said as we were walking through a dusty patch of road to a food stall outside the gates of the research station, 'there is nothing new in Kawanda, no building, no road, no nothing the government invested in recently'. It is true that some laboratories were not refurbished since the 1960s, books and documents are left to rot, laboratory equipment decays and odd pieces of equipment that nobody knows what they were used for are still standing around in some laboratories and storage rooms (Geissler et al., 2016; Mika, 2016). Nonetheless, at least two buildings were erected after the British left, one with a grant from the World Bank, the other by a Korean development organization, backup generators were installed, a number of greenhouses were built and even an additional lab was under construction. For many researchers, it was all the same and no one mentioned this as a sign of progress. Scientists linked their experience of working in decaying infrastructures at Kawanda to a broader pattern visible across Uganda: to government facilities dying out, the decrepit state of public schools or public hospitals, the lack of investment and planning (in anything but roads) and the corruption of a ruling elite that filled its own coffers while not providing the basic means to keep experimental work at Kawanda going. The incongruities between well-funded research projects and the

ruination of basic power and water infrastructures creates tensions and breakdowns, where Ugandan biologists must stand in and hold the infrastructure together. Researchers experience carrying water in jerrycans and enduring exposures because of the dysfunctional fume hood as humiliating and degrading; toxicity resides in the harm these events leave these scientists with, a harm that can be both physical and psychological.

Critique and distributed culpability

In Kawanda, there is much pride in what one is able to accomplish, but there also is shame for not being as modern as one should be. There is shame for not being able to turn the lab into a placeless one where there aren't constant reminders of its geographical location ('This is Kawanda!'), and where well-educated scientists don't have to insert themselves into infrastructural gaps, exposing themselves to substances that can harm their health. It puzzled me at first that toxic exposures, while fretted about, were hardly addressed in critical conversations at the lab; these critiques instead focused on the corrupt and uncaring government of Uganda that dooms researchers to backwardness. One of the main reasons why researchers do not focus their critiques on toxicity may be its elusiveness, the difficulty of establishing evidence and causal links, which in turn is exacerbated by the slowness and variability with which chemicals harm bodies (Liboiron, 2016; Tironi, 2018: 450, 451). A further reason lies in the nature of labor relations that make it difficult to speak up personally.

Contracts for research assistants, those doing most of the actual laboratory work in Kawanda and therefore those most exposed to toxic substances, are short-term and project-bound and unfold in a wider culture of volunteerism (Whyte, 2015: 208). Consider Monica, who came to Kawanda in 2015 right after finishing her Bachelor's degree at Kyambogo University. She came as a volunteer, making herself available without reimbursement in the hope that she might eventually be employed. Like many others, every day she traveled one-and-a-half hours by matatu taxi through congested Kampala to reach Kawanda around 8:00am in the morning. She did this for nine months without pay, her neat, well-ironed and spotless clothing glossing over the fact that she often worked without a lunch to sustain her. Then, after she had already taken over a central role in the tissue culture lab for several months, she was finally put on the payroll, receiving a small salary without being offered a contract. After more than a year, she received a contract for a few months, but it had already been decided that her work was no longer needed in the next phase of the project. Kawanda, for Monica, was rife with frustrations, but she was careful and hesitant in airing them, apart from general gestures toward the government, people up there and far away. She meanwhile found work elsewhere, and new graduates volunteered at the institute. Apart from the administrative staff, only postdocs have permanent salaried jobs. These types of government jobs, in spite of their low pay, are coveted in a setting of rampant youth unemployment (Whyte, 2015: 208). Young graduates in Kawanda know that they can be replaced quickly, that they have to prove themselves indispensable to projects and perhaps get the opportunity to travel abroad for a master's degree or a PhD. They are structurally poorly positioned to voice concerns about toxicity. 'It affects you but you do the work', one lab technician stated, though he complained that his nose had been constantly congested since he started to work at

Kawanda. Like him, many accept exposures as part of the everyday personal sacrifices they have to make to work in Kawanda.

Dreams of postcolonial progress and nation-building in Uganda, and in many other places, still congeal around public infrastructures.¹² Even though there is a strong reliance on foreign funding for research projects and one could surmise the state is thereby weakened, it still serves as a reference point for expectations and claims in many African contexts.¹³ This may explain why Ugandan researchers blame their government for corroding infrastructures and turn a blind eye to the modalities of international science collaboration. The idiom of collaboration suggests an equality between partners, having overcome racist and colonial pasts, and therefore has to make persistent material inequalities invisible or 'unknown' in day-to-day work (Geissler, 2013: 18; Okwaro and Geissler, 2015). Ugandan scientists do not mention their toxic exposures to their collaborators, and they do not extend their critiques to the Gates Foundation or other donors for bad or incomplete planning – that is, for simply transferring the microscope in isolation and pretending it could work seamlessly (Latour, 1993: 98). The Gates Foundation, a main player in global health and development, in particular has been criticized for its role in hollowing out national governments by setting its own funding priorities and creating their own closed data-driven mechanisms of accountability (Mahajan, 2018; McGoey, 2015). When Buah and his team worked with a malfunctioning fume hood, this was due to the tight scheduling of their work and the need for results to achieve the required progress that would allow them to apply for an extension of the project. To be sure, other research funders also demand results before granting further funding, yet the Gates Foundation is especially exacting in its evaluation of projects as good or bad investments and is quick to close down projects that fail to meet the targeted milestones (McGoey, 2015: 225, 226).

Moreover, while project-based funding from the Gates Foundation is generous, most of its project funding in the Global South goes directly to organizations and institutions based in the Global North, as in the case of QUT and its partner in Kawanda (McGoey, 2015: 289, 290). Ugandan researchers hastened to relate to me that the forms of mutuality and partnership established with Dale and his team at QUT, unlike in other projects, were exemplary. Still, the fact that a wealthy, already well-endowed institution received yet another prestigious grant and presides over funding, even when perceived as benevolent, solidifies both the power imbalances and material inequalities between research settings in Australia and Uganda. Such asymmetries constantly put Ugandan researchers into a position where they have to apologize to their partners for delaying the work, due to chemicals being out of stock, power being unstable or water being out, and where due to this perceived 'lack' on their part – though certainly no fault of their own – they are inclined to engage in risky practices just to continue doing the work, to prove that one can in fact do molecular biology in Uganda.

Unlike during the 1970s and 1980s, funders today usually do not include budgets for basic infrastructures beyond project-related expenses. Hence, at least partial blame for the situation of unequal toxic exposure at Kawanda has to be placed on donors and research funders for pretending that to function well, a Ugandan lab does not require permanent spending on materials and staff to service and maintain the infrastructure (Okwaro and Geissler, 2015: 505). Furthermore, near the QUT Campus in Brisbane,

many manufacturers of lab technologies run service offices, specializing in repair and maintenance, shortening the known problematic distances between makers and users of technology (Orr, 1996; Schaffer, 2011: 710). This service and labor segment is entirely missing in Uganda. Given the overall isolation of this lab, the distance from such services and other specialized biotech centers, and the resulting difficulty of skilled maintenance of highly specialized research technologies, funding agencies pretend in bad faith that Kawanda could function like any other lab and close their eyes to the everyday difficulties of researchers.

Kawanda, as Uganda's first biotech lab, is time and again held up as a sign of modernity, scientific progress and development. However, it still often enough has to pretend to be up-to-date while having to rely on molecular connectivity and simple rural techniques of carrying water in jerrycans to avoid infrastructural collapse. Neither technologies nor labs function in isolation. The leftovers of colonial infrastructure materially persist, as do patterns of the distribution of power between Ugandan and foreign research facilities. The research institute at Kawanda was inaugurated with clear power relations between British colonizers in charge of research and subordinate Ugandan staff. Though tropes of partnership abound today, Ugandan scientists still find themselves at the lowest end of the hierarchies of scientific practice; they have neither the ability to set agendas nor to gain needed funding independently of projects directed from elsewhere. While distributions of power and resources follow old patterns, it has become harder to attribute responsibility for present deficiencies to single causes or agents. Should blame be laid on how molecular biology works internationally, how science funding or philanthropy is organized, how corrupt governments misuse funds, how educational institutions fail to inculcate risk aversion or how public-private infrastructures distribute water and power? Or all of the above?

Infrastructures go beyond such clear-cut questions and attributions of responsibility. Infrastructures especially in postcolonial settings exceed attempts to fully control them, due to their moral complexity and spatial vastness, their accretion over a long period of time, and the unavoidability of an incomplete integration of older and newer materials (Anand, 2017: 187, 188). Ugandan scientists therefore appear realistic about how and where they place their critiques: They recognize they won't be able to simply change a transcontinental web of relationships that causes their bodies harm, and they know voicing critiques can cause friction with their collaborators (Geissler, 2013). Where a previous scholarly concern with structure was about unmasking power working behind people's back, the concern with infrastructure directs analytical attention to the effects of haphazard accretions, historical contingencies and a mixture of structural and material inequalities. Infrastructure hides power, distributes it between distant actors and materials, and thereby often disperses a clear sense of accountability, producing this particular experience of opportunity and fear about occupational safety among Ugandan biologists. Ethnographic attention to such complicated transnational labor relationships and the toxic remains they produce can nonetheless point to new forms of exploitation. It can point not only to a direct exploitation of labor power but to the unequal burdens connected to late-industrial production that still tend to concentrate in spaces of abandonment and dispossession – that is, among poor, black and queer people.¹⁴ Toxic remains are not what critiques address; they are simply what accumulates in terms of significations, affects and bodily experiences of exposure to infrastructural inequality.



Figure 4. Dr Tindamanyire after he managed to get Southern blotting to work at Kawanda, August 18, 2017 (S. Calkins).

What remains: Toxic exposures and partial culpability

At Kawanda, Ugandan researchers are accomplishing a remarkable feat, something that goes unnoticed by their international science collaborators who might press them for deadlines but are unaware of the nitty-gritty troubles of research in uneven infrastructural palimpsests. Dr Tindamanyire shows real joy when he finally held evidence in his hands that Southern blotting, a standard procedure in molecular biology, was working. Dr Tindamanyire had worked hard for weeks in 2017 to get it to run at Kawanda; others before him had failed repeatedly and people had started to believe ‘Southern’ was something one simply couldn’t do in Uganda. Dr Tindamanyire felt satisfied and yet he was aware it is nothing he could pride himself for beyond the perimeters of Kawanda: it is, after all, simply a standard procedure elsewhere (Figure 4).

Ugandan scientists find themselves at the margins or ends of a global research infrastructure that enables the practice of molecular biology. Positioned like this, they have to bear toxic exposures when this global research infrastructure breaks down and they have to work in unsafe, polluted surroundings. The everyday anxiety around toxic exposures in Kawanda indicates Ugandan scientists’ lack of alternatives, but also their persistence in continuing their work, even if they bind themselves in substance and sentiment down to the molecular level to unequal international research infrastructures. Toxicity, I have suggested, is a bodily way of registering infrastructural neglect by the government and donors alike, a neglect to care and protect researchers’ bodies from harm, a neglect that is humiliating and reproduces differences in occupational health and scientific standards between Uganda and Australia. Corroding infrastructures and chemical exposures thus enable Ugandan scientists’ bodily experiences of postcolonial asymmetries in north-south science collaborations, where the distribution of harms and benefits of scientific

work follows colonial patterns. In such relationships, speaking and speculating about toxicity is a part of a lab-internal critical discourse wherein frustrations are aired about a mismatch between expectations surrounding what infrastructure should be like – according to researchers’ training and understanding of work safety procedures – and what it actually is like.

By framing this article in terms of ‘toxic remains’, I have sought to draw attention to what sacrifices – be they physical harms related to chemical exposure or the sense of degraded possibility that go along with infrastructural decay – Ugandan biologists make by standing in for infrastructural shortages and breakdowns. Previously, I had been skeptical about Simone’s (2004) point that people become infrastructure in African settings when they are made to stand in for failing infrastructure to keep the circulation and connectivity alive. I felt it risked extending the notion of infrastructure too far. My experiences in the Ugandan lab have, however, convinced me that people do become infrastructure, though in ways that Simone (2004) may not have foreseen. In Kawanda, when scientists insert themselves into infrastructural gaps and forge molecular ties with toxic chemicals, they not only become part of the infrastructure based on the labor they perform or their skill at maintenance, but their bodies also literally become the conduits of their scientific practices. Their bodies register these histories of toxic exposure; they can wear out from use and may end up ruined. Such local biochemical relations point to lurking dangers and leave little room for warm feelings about repair, bottom-up subversion or improvised solutions to infrastructural problems.

It is important to not only study bodies that are harmed and suffer but also to address the structures of power that cause this harm and perpetrate violence (Liboiron et al., 2018; Tuck and Yang, 2014: 223). Yet a call to study structures presupposes more or less identifiable roles, such as perpetrators, victims or clear causalities that can be named and that operate behind research participants’ backs. Infrastructure, however, draws attention exactly to what lies between, can’t always be named, and normally is backgrounded in critiques. In the flaky palimpsests that have accreted over many decades in many countries of the Global South and increasingly the Global North, infrastructures exceed clear planning and control. They obfuscate clear responsibility, disperse agency and complicate facile attributions of blame. Power may not be manifested in the clear structural terms that allow the establishment of straightforward causal chains where someone is made responsible for everything. But power’s operations still produce discernible patterns of partial culpability, patterns of things that are circulated and things that are withheld, that are known and unknown (Geissler, 2013), patterns of lives that are valued and protected and lives that are devalued through harmful exposures that remain hidden from the usual accounts of scientific practice. Such patterns are not only toxic in material and metaphorical terms, but also articulate possibilities and successes that are fought for much harder in unstable places.

Acknowledgements

The fieldwork for this article was financed by the Max Planck Society. Immense gratitude is due to the scientists at Kawanda and QUT, and especially to James Dale and Wilberforce Tushmereirwe for their steady institutional support during field research. Many thanks to Stephen Buah, Mara Erlenmaier, Kristiane Fehrs, Wenzel Geissler, Sophie Nakueira, Eva Riedke, Ursula Rao, Nick

Shapiro, Jimmy Tindamanyire and Tyler Zoanni for their comments and suggestions. I'm grateful to audiences at the AAA panel on 'the ends of infrastructure', the German African Studies Association panel on 'infrastructure's intimacies', the research colloquium at the department of Integration and Conflict at the MPI for Social Anthropology, and the Vienna ethnography lab. I also thank the generous anonymous reviewers of this piece who offered valuable feedback and suggestions.

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Notes

1. Most names in this article have been changed.
2. Larkin (2013: 336), however, points out that this doesn't mean that infrastructures are 'invisible', given their signification of modernity, progress etc.
3. For some recent examples from science and technology studies, see Shapin (1989), Mol et al. (2010), Droney (2014), Okeke (2020) or Tousignant (2013a).
4. In Kinshasa, where infrastructures often breakdown or are absent, De Boeck (2012) similarly speaks of 'bodily infrastructure' and argues that failures of states to build and maintain infrastructures cause people to become the infrastructure (see also De Boeck and Plissart, 2004).
5. For instance, Wendland (2010) examines the makeshift improvizations of Malawian medical students that result more from a lack of infrastructure than its breakdown, and she describes the debilitating and fatal consequences for patients. Livingston (2012: 6), in her research in a Botswana cancer ward, finds daily improvisation to be the defining feature of biomedicine in Africa, often forcing clinicians to make life and death decisions. In a similar setting of malfunctioning and inadequate infrastructure, Street (2014: 226) examines how Papua New Guinean doctors improvise and experiment with biomedical technologies in an underfunded government hospital; though offering a bleak outlook, she still links improvisation to hope.
6. Focusing on the dark side of 'African science' and its tendency to improvise, Droney (2014: 375) recounts an anecdote of how chemicals were discarded in a plugged sink and were able to vaporize in a Ghanaian lab before researchers noticed and fixed the problem. See also Doherty's (2017) case study of *boda boda* riders in Kampala. He likewise argues that Simone's account of infrastructure 'is unable to take up the ways in which these infrastructural worlds can be experienced as unfair, exclusionary, degraded, and degrading by those who live and work within them' (p. 205). Mavhunga (2017: 7, 8) puts forward a different but equally important critique of tinkering in Africa, namely, that the tendency to see tinkering pervasively at work across African sites portrays them as places where only technological adaptations, but not innovations, can occur. Studying a Chilean lab, Ureta (2021: 20) takes a different approach by foregrounding 'ruination science' as a type of 'creative and flexible', adaptive, impure and improvised scientific practice that is driven by an ethical commitment and care for holding fraying pieces of equipment together. Though he astutely notes that 'we have the duty to resist the temptation of merely celebrating ruination science', his account nonetheless tends to paint a rosy picture of such ruination science and advances it as the better adapted science to working and living in the damaged landscapes of the present.
7. This is common for medical and life-sciences research in the Global South, especially after structural adjustment programs in the 1980s (see, e.g. Crane, 2013; Geissler and Tousignant, 2016; Okwaro and Geissler, 2015; Okeke, 2018, 2020).
8. Where Winner (1986) and Akrich (1992) highlight the stability of technology and infrastructure as well as their discernible techno-politics, more recent scholarship has tended to

- emphasize infrastructure as a continuous practice and fluid process (e.g. Anand, 2017; Guma, 2020; Howe et al., 2016; Jensen and Morita, 2015; Larkin, 2013; Niewöhner, 2014; Street, 2012, 2014).
9. For the sake of comparison with other sites of science in African settings, see Lachenal (2015), Geissler et al. (2016) and Tousignant (2018). See Meinert and Whyte (2014) for the increasing ‘projectification’ of development. What is specific about Uganda’s postcolonial history is that after initial dreams of progress and self-determination, and the mismanagement in the decades after independence, research work at Kawanda came to a nearly complete halt in the 1970s under Idi Amin, who forced many intellectuals, doctors and scientists to flee the country. For the impact of structural adjustment programs, see Crane (2013).
 10. For overviews of the different material histories of colonial biomedical and biological research in African settings and their effects on scientists, see Lachenal (2011), Geissler (2015b), Geissler et al. (2016) and Tousignant (2013a, 2018).
 11. I follow the lab convention of Ugandan scientists, referring to research assistants on a first name basis, and to researchers with PhDs as Dr and last name – even though Dr Tindamanyire likes to be called ‘Jimmy’.
 12. See, for instance, Mains (2012) and Harvey and Knox (2012) for the popular ideas that both roads and dams bring development.
 13. See Geissler (2015a: 8–10) and Tousignant (2018: 103–104) for the expectations entertained toward and critiques of the state at African scientific institutes. Tousignant (2013b) similarly argues that young pharmacists in Senegal remain attached to forms ‘of stability, regulation and citizenship’ that are associated with the public governmental sector.
 14. A number of studies have recently addressed the inequalities aggravated by different chemical exposures. See, for example, Hecht (2012) for unequal exposures in uranium mining, Murphy (2008: 698, 2017: 496, 497) and Shapiro (2015: 371) for poor home owners in North America, Chen (2020) for how exposures affect queer bodies and panics about Chinese lead reinforce racial stereotypes, Weston, 2017: 80, 81) for how governmental thresholds of ‘safe radiation levels’ affect less mobile local populations near Fukushima, and Blanchette (2019: 15) for how exposures to chemicals in US pig farming affect a disenfranchised and predominantly immigrant labor force).

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