


Research Paper

Assessment of WASH infrastructure in schools in Central Sulawesi, Indonesia using structured observations and principal interviews

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ABSTRACT

Adequate water, sanitation, and hygiene (WASH) facilities in schools are vital, especially for girls. This study addresses a gap in assessing the adequacy of WASH facilities' repair at schools affected by natural hazards. Central Sulawesi was used as a case study where principal interviews were conducted at 26 schools, and structured observations were made at 18 schools, 3 years after the earthquake in September 2018. Ten of 26 principals reported no damage to the toilets from the events of September 2018. Among those who did, a third felt that the fixes insufficiently met basic needs and that they did not deliver WASH services as well as they used to. Not all WASH inadequacy stemmed from the earthquake. Structured observations revealed that most toilets lacked soap, open water reserves were placed next to non-flush latrines, posing a high potential for vector-breeding, and there were inadequate facilities for menstrual hygiene management, including no bins. Recommendations include ensuring a supply of soap, adding lids to water storage containers, and providing sanitary napkins and lidded bins. Observations suggested that private schools provided a better level of WASH service than state schools, and schools in more hazardous zones did not take longer to recover.

Key words: Central Sulawesi, Indonesia, Palu, post-disaster schools, sphere Humanitarian framework, structured observations, WASH

HIGHLIGHTS

- Structured observations and interviews with school principals were used to assess WASH facilities, 3 years after the 2018 earthquake in Central Sulawesi, Indonesia.
- Coping mechanisms for damage to main pipelines include storing water in buckets in toilets.
- State schools lagged behind private schools in WASH facilities.
- Inadequate menstrual hygiene management in schools.

1. INTRODUCTION

Limited research has been conducted regarding the recovery of lifeline infrastructure services impacted by natural hazards (Pribadi *et al.* 2021), let alone within a school context where damage to infrastructure has the potential to affect students' ability to return to school.

On 28 September 2018, an earthquake of magnitude 7.5 struck northwestern Central Sulawesi, Indonesia, resulting in a tsunami, liquefaction, and landslides. Among other effects such as injuries, deaths, and damaged homes, the earthquake

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also damaged water, sanitation, and hygiene (WASH) facilities and exacerbated WASH inadequacies at schools in Central Sulawesi in Indonesia. Prior to the earthquake, the WASH situation was already lacking: 36% of secondary schools across Indonesia had no handwashing facilities (JMP 2020), indicating a mismatch between government policy (Ministry of Education and Culture 2018) and reality on the ground. After the earthquake, only 14% of female school toilets in the affected Central Sulawesi province were assessed to be in good condition, while 53% were assessed as heavily damaged (Ministry of Education and Culture 2020). By the end of 2019, UNICEF assessed that access to education had largely returned to pre-earthquake levels; however, it noted that many children were already not attending school prior to the earthquake, indicating ‘underlying issues beyond school repair’ (UNICEF 2019).

The tsunami that occurred was unusual, and the resulting flow-liquefaction was one of the most extreme recorded worldwide (Syamsidik *et al.* 2019; Pribadi *et al.* 2021). The city of Palu had a contingency plan in place since 2012, prepared for earthquakes with a magnitude of 7.4 on the Richter scale, and for tsunamis (Pribadi *et al.* 2021). At a national level, the Indonesian National Disaster Management Authority declared 26 April, 2017, as the National Disaster Preparedness Day (Pribadi *et al.* 2021). Traditional buildings in Indonesia have been built to be earthquake-resilient, as evidenced by structures in Yogyakarta, West Java, West Sumatra, and Nias Island (Pribadi *et al.* 2021). However, the large number of casualties was attributed to insufficient tsunami mitigation interventions, as well as to the unique characteristics of the earthquake that made it difficult to prepare for (Syamsidik *et al.* 2019). The National Mid-term Development Plan 2015–2019 received criticism for only mentioning Public Health Resilience once (Warsito *et al.* 2021). In response, following the 2018 earthquake, the National Disaster Management Plan 2020–2024 was published in 2019, followed by the Indonesian Disaster Management Master Plan 2020–2044 in 2020.

In response to the damage caused to WASH facilities, the federal and provincial governments, along with several non-governmental organisations, allocated resources for rehabilitation efforts. By the end of 2019, UNICEF repaired 322 latrines, constructed 1,251 new latrines, and implemented faecal sludge management in 1,750 latrines in the affected areas (UNICEF 2019). Wahana Visi (World Vision), meanwhile, constructed 1,166 toilets, with 336 of them located in schools (mostly in Palu, followed by in Donggala, Sigi and six in Parimo) (Wahana Visi 2020). Wahana Visi also distributed 21,532 sanitary products, constructed 37 bore holes, constructed seven pumping units, constructed five water treatment plants, and distributed 25,585 hygiene toolkits, 1,480 handwash with soap packages, and 31.4 million litres of water (Wahana Visi 2020). Restoring power was crucial for ensuring the availability of water as electricity powered the water pumps (Yulianto *et al.* 2021). However, Yulianto *et al.* (2021) found that even after power was restored, the groundwater in Palu City remained cloudy and unfit for consumption.

This paper examines the perception of school principals regarding the impact of the natural hazard events that occurred on 28 September 2018, on WASH facilities in schools located in Central Sulawesi. Furthermore, it examines the adequacy of solutions implemented to address these impacts as perceived by school principals 3 years after the earthquake. Through structured observations and principal interviews, the study compares the results of state and private schools to examine the hypothesis that private schools, being better resourced, deliver better WASH services to their students. It also compares the WASH situation in state schools in different hazard zones to test the hypothesis that schools exposed to more intense hazards are likely to offer worse WASH services after 3 years.

1.1. Review of the broader context of the effects of inadequate WASH facilities at schools

Warsito *et al.* (2021) identified various categories of diseases that emerged in the aftermath of hazards, with three of them directly linked to the adequacy of WASH facilities. These include water contaminated by faeces, stagnant pools of water that promote vector-borne diseases, and infections resulting from wounds. There is a consensus view among researchers regarding the positive impacts of improved water quality, quantity, and sanitation on health (Cairncross *et al.* 2010). Studies on the effect of handwashing with soap have been consistent, showing a reduction of 42–48% incidence in diarrhoea and a reduction in diarrhoea caused by excreta disposal (Cairncross *et al.* 2010). Diseases not only lead to school absences, but in the case of malaria, can also result in cognitive impairment even after recovery (Fernando *et al.* 2010). A study on mosquito vectors conducted in schools in two municipalities in Colombia found that common breeding grounds for mosquitoes were containers for bottles, discarded food waste, plastic cups and cans, followed by buckets for water storage, large concrete wash-basins, and ground tanks for water storage (Olano *et al.* 2015).

Inadequate provision of WASH facilities goes beyond reducing disease transmission pathways and can limit children’s, and in particular girls’, ability to attend schools. Garfias Royo *et al.* (2022) reviewed literature and found that poor-quality or no

WASH facilities pose hygiene challenges to students while at school, leading to feelings of disgust, shame, embarrassment, fear for safety, and a longing for greater privacy and comfort, particularly among girls during menstruation. Avoidance of toilets due to unpleasant odours, uncleanliness, fear, and bullying can also lead to health problems, such as constipation, urinary tract diseases, and incontinence (Vernon *et al.* 2003). In a study conducted in 2002, researchers found that many children avoided using school toilets at two selected school sites in England and Sweden. Similarly, a study conducted in rural China in 2019 found that toilet cleanliness was the primary consideration for students to use the toilets in the campus, and the visual experience of the overall cleanliness of the toilets had the most significant impact when students used the toilets (Shao *et al.* 2021). In the neighbouring typhoon-affected Philippines, girls needed both instructional resources as well as functioning WASH and sewerage facilities to stay in school for a longer duration (0.23–0.32 years of additional education) – instructional resources alone were not sufficient to induce statistically significant increases in the duration of school enrolment for girls, unlike boys (Cas 2016).

Whether a privately funded school is a relevant factor in the provision of WASH facilities is not well documented in the literature. In theory, WASH facilities would be of higher quality in private schools (a) because they are better resourced and (b) because they must demonstrate superior services to justify their fees. A comparative analysis from a sample of two private and two state schools in the district of Addis Ababa suggested that this could be the case (Deyasso & Ashenafi 2022), though their sample is too small to be conclusive. Extending the literature search beyond WASH, James *et al.* (1996) concluded that in the case of 68,000 Indonesian primary schools in the 1990s, more money is likely to bring better school quality and efficiency. However, the study did not make conclusions regarding the effect on physical facilities. Similar findings have been observed in other parts of the world. Studies in Pakistan and in Kenya have shown that private schools outperform state schools in terms of academic performance (Andrabi *et al.* 2008; Bold *et al.* 2011).

Mahful *et al.* (2019) studied the provision of education in refugee camps following the 2018 earthquake in Central Sulawesi. Their study indicated that education was lower in the government's priority list, with many children dropping out of school. However, the authors did not look at WASH services in temporary schools (Mahful *et al.* 2019). Wekke *et al.* (2019) have claimed that clean water and sanitation were among the most urgent and important needs of communities affected by earthquake in Central Sulawesi, alongside school uniforms, schoolbooks, and equipment, but did not present specific evidence to build this case.

The literature refers to several phases of recovery, as depicted in Figure 1. Chester *et al.* (2021) refer to a 'relief' phase in the immediate aftermath of the disaster to manage the initial chaos, lasting several weeks. This is followed by a 'rehabilitation' phase once the initial chaos has calmed, and immediate threats reduced. Basic services are brought back online. Following this is the long-term 'reconstruction' phase which can last a decade, whose tail-end overlaps with the post-disaster development phase. Kates *et al.* (2006) sliced the post-disaster recovery slightly differently – calling the first 10 weeks the 'emergency'

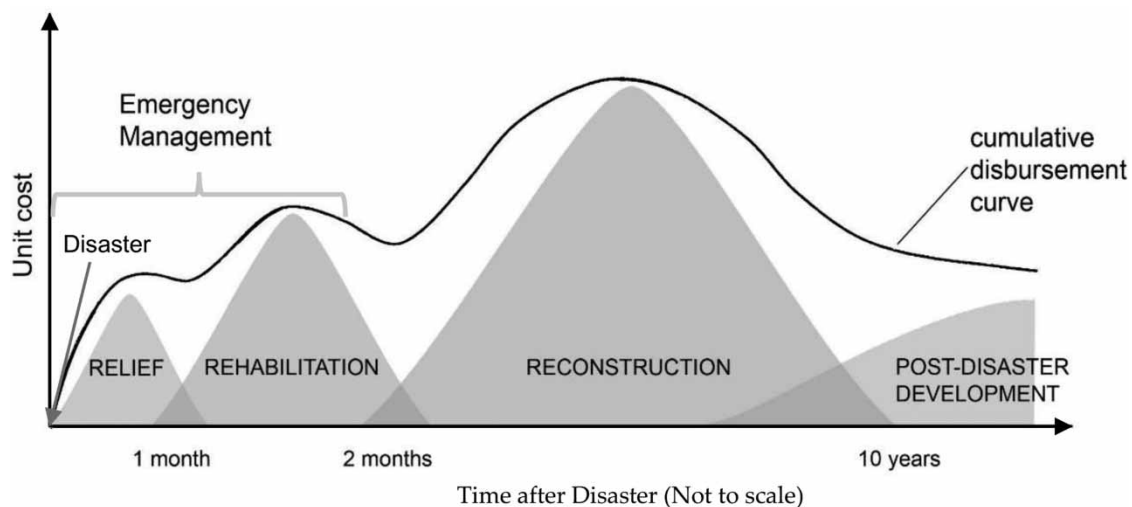


Figure 1 | Disaster response phases towards resilience. Source: Chester *et al.* (2021).

phase, the next 40 weeks the ‘restoration’ phase, and the following 950 weeks the ‘reconstruction’ phase. According to either classification, our study falls within the ‘restoration’ phase.

2. METHODS

2.1. Framework for WASH assessments

Relevant frameworks were considered to analyse the results of this paper. These included Sommer *et al.*'s (2017) Toolkit for Menstrual Hygiene Management in humanitarian responses; UNICEF and GIZ's Three Star Approach for WASH in Schools (UNICEF and GIZ 2013; Abel 2020), and six further frameworks considered by Pacheco *et al.* (2021). Of all of these, the Sphere Humanitarian WASH standards were identified as the most appropriate framework.

In the Toolkit for Menstrual Hygiene Management in humanitarian responses, Sommer *et al.* (2017) offered a hierarchy of menstrual hygiene management needs, starting with the provision of basic supplies at the base of the pyramid of needs. Information, facilities, safety and privacy follow, and the notion of dignity sits at the apex of the pyramid. The toolkit is not, however, comprehensive in addressing all WASH facilities. It neither covers safety from vector-borne diseases nor rubbish collection and dispensation beyond those related to menstrual waste.

The Three Star Approach for WASH (UNICEF and GIZ 2013; Abel 2020) does not cover post-toilet cleaning, use of bins in toilets, or solid waste management. It also does not separate quality and quantity of drinking water (UNICEF and GIZ 2013).

Pacheco *et al.* (2021) conducted a review of the Sendai Framework for Disaster Risk Reduction; the Sphere Handbook for Humanitarian Response; Build Back Better; Build Back Better in Recovery, Rehabilitation and Reconstruction; Guide to Developing Disaster Recovery Frameworks; and 2030 Agenda for Sustainable Development – Sustainable Development Goals (SDGs). Among these, the Sphere Humanitarian WASH standards provide a plethora of metrics with respect to assessing at the school level water supply, personal hygiene, excreta management, vector control, and solid waste management. They can, therefore, help to establish links between poor WASH and health. The Sphere standards also include gender-related metrics, such as those related to menstrual hygiene and to the perceived safety of toilets by girls. In doing so, they can be used to identify links between WASH facilities and school attendance and enrolment (Cas 2016; Garfias Royo *et al.* 2022). The Sphere Humanitarian framework was, therefore, assessed to provide the most comprehensive framework for assessment and hence was adopted for this study.

2.2. Data collection

Data were collected in July and August 2021, almost 3 years after the earthquake. To assess WASH adequacy, we collected visual data using structured observations. Supplementary material, Annex 1 and Annex 2 show the prompts given to field data collectors regarding what to note down and capture pictures pertaining to WASH conditions relating to drinking water stations (sources of drinking water); handwashing stations (presence of soap and water, and source of water); toilet locations and toilet conditions; and presence of litter and solid waste disposal provision.

In addition to structured observations, a combination of structured and semi-structured interviews was conducted with school principals to assess the current WASH situation compared with the situation prior to the earthquake. Also, to receive feedback on the barriers faced in the recovery phase. We chose to interview principals as a part of and in addition to the structured observations as they could speak to the management of facilities, access resources, their knowledge of external interventions and in most cases, memories of how the 2018 earthquake affected the school and the adequacy of the response to the effects and in building resilience. Themes of the interviews covered how the 2018 earthquake affected the school's WASH facilities, the adequacy of response to its effects, and current practices related to WASH services and infrastructure.

Sampling was purposive so that we were able to assess schools that had experienced different levels of hazards. The level of the hazard zone that the schools had been designated to by the government in 2019 following the earthquake was used as a proxy for this (Kemdikbudristek 2021). Zones ranged from ‘out of zone’, meaning low susceptibility to hazards to ‘zone 4’ denoting the most dangerous zone where new development was prohibited. We also visited both state and private schools across the regencies of Palu, Sigi, and Donggala.

Sampling achieved was also based on convenience, due to official COVID-19 protocols restricting data collectors' movements from visiting our first choice of schools. Data collection was managed and carried out by our Indonesian research partners at the University of Syiah Kuala's Tsunami and Disaster Mitigation Research Centre (TDMRC) and at Tadulako University located in Central Sulawesi. We were unable to ensure that data collectors recorded results for every school they

surveyed or that interviewers obtained responses for every question posed to principals. Thus, the total number of observations per metric varied.

There were two main cleavages to the sampling achieved:

1. sampling state versus private schools – see [Table 1](#), and
2. sampling schools by the hazard zones they were assigned to retrospectively by the government in 2019 – see [Table 2](#).

With this sampling and based on our review of the literature, we hoped to test the following two hypotheses:

1. private schools, being better resourced, would offer better WASH facilities than state schools; and
2. schools in the more hazardous zones would take longer to recover and so have the worst state of WASH facilities.

3. RESULTS

This section is divided into two parts: the first part shows school principals' recollections of the impact of the events of 28 September 2018 on toilets, together with their impressions of the fixes. The second part shows the situation of WASH facilities that were observed and that principals reported in July and August 2021. The results have been presented at an aggregated level to depict a general view of WASH facilities at schools in northwestern Central Sulawesi.

3.1. Principals' memories of how the earthquake affected WASH

The most common reported type of disturbance was the loss of pumped water due to power outages (18 principals) and the most common reported type of damage was broken pipes (8 principals), followed by shattered ceramic toilets and damaged sinks (6 principals each), sewerage seepage (5 principals), and flooded septic tanks (2 principals). Eleven principals reported that the earthquake had caused the damage, a much greater number than those reporting other hazards – liquefaction was reported by three, fire caused by the hazards by three, and damage by tidal waves by two.

All 26 principals reported that their schools had experienced earthquakes. Ten principals reported no damage to toilets from the events of 28 September 2018. Eleven principals said that the earthquake had damaged toilets. Six principals reported that their schools had experienced liquefaction, and three of them answered that liquefaction had damaged toilets. Three of three principals who said that their schools had experienced fires answered fire had damaged toilets. Six principals reported that their schools had experienced tsunami waves, of whom two answered that tsunami waves had damaged toilets. Two principals reported that their schools had experienced floods, but none reported damage to toilets by flooding.

For most schools (16/21), principals perceived that the impact of the events of September 2018 on WASH infrastructure did not disrupt teaching. For those that did see a disruption, two principals reported that teaching was briefly stopped, but then there was a temporary and later a permanent fix; two reported that teaching stopped briefly but then they got a temporary fix; and one reported that damage to toilets continues to disrupt teaching – see [Figure 2](#). Relating to fixes, four principals reported using portable toilets at some point, one reported that their school used a new wooden toilet, three reported using neighbours' or neighbourhood toilets.

Table 1 | Sampling achieved for state vs. private schools

	State schools	Private schools	Total
Principal interviews	22	4	26
Structured observations	14	4	18

Table 2 | Sampling achieved for state schools according to the government's 2019 multi-hazard susceptibility zonation map

	State schools – out of zone or zone 1	State schools – zone 2	State schools – zones 3 or 4	Total
Principal interviews	9	8	5	22
Structured observations	5	5	4	14

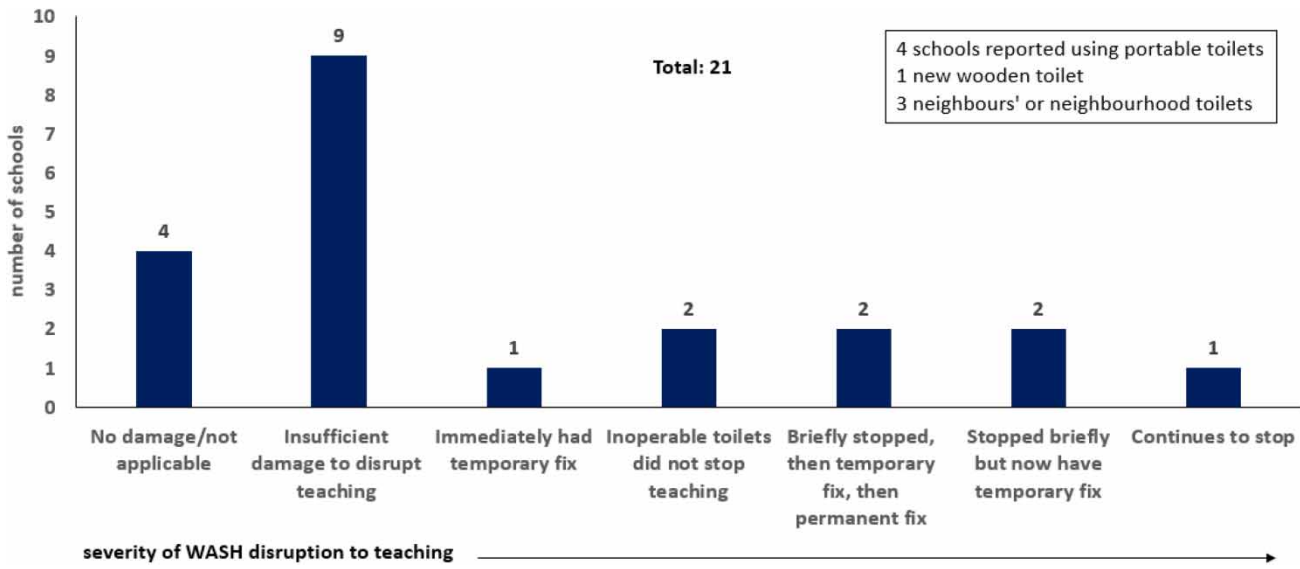


Figure 2 | Impact of damage of toilets on teaching. Source: Principal interviews.

For 15 schools that had a fix to their toilets in some form, Figure 3 shows how principals felt about fixes to the damage to toilets caused by the 2018 earthquake. A third of those principals felt that the fixes did not sufficiently meet current basic needs, and that the current status of WASH was not as good as it used to be, was not resilient to the causes of the initial damage and did not protect users and the community from the transmission of disease.

Understanding why a third of principals felt that WASH services were not meeting basic needs and were not as good as before, we investigated the barriers to a full recovery of WASH facilities and identified several. These barriers were lack of toilets in a temporary school, substandard or temporary toilets in permanent schools, lack of retrofitting and inadequate

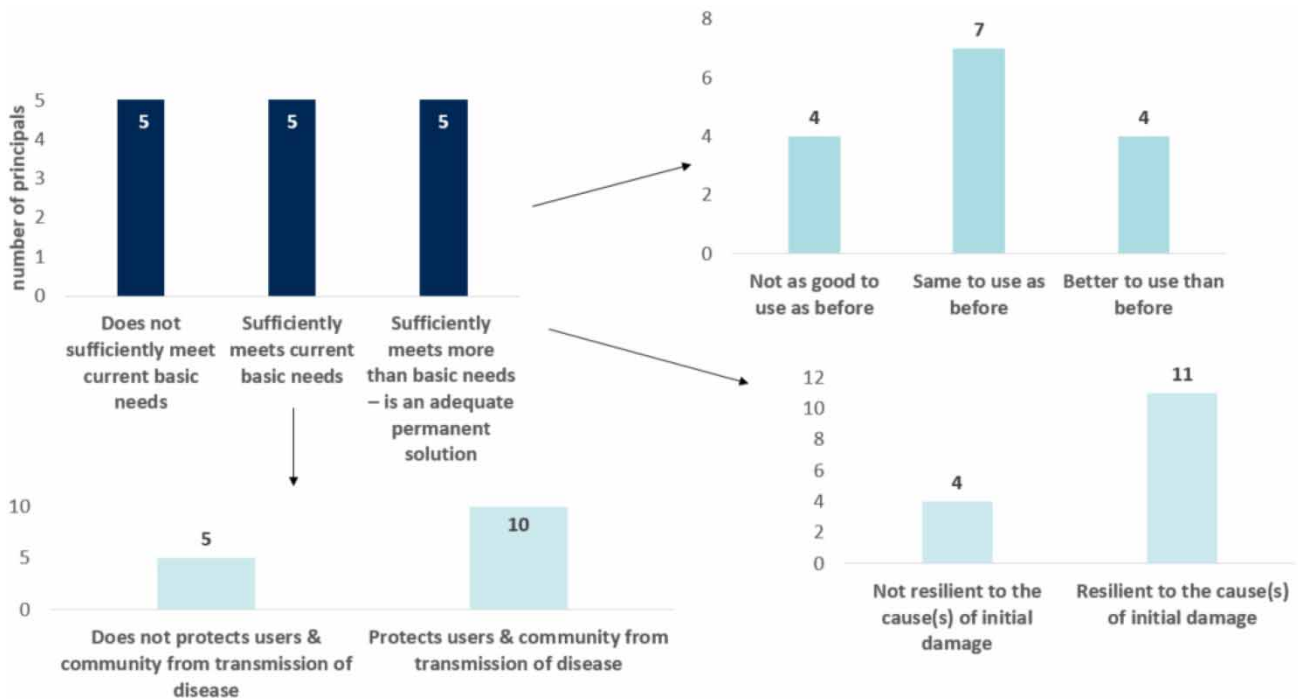


Figure 3 | Principals' feelings about fixes. Source: Principal interviews.

water. One principal reported having no toilets in their temporary school and recommended offering a portable toilet. Two principals reported substandard or temporary toilets instead of permanent toilets in their school and one of these principals wanted their old permanent toilets reconstructed. Another complained that there had been no retrofitting in their toilets, and recommended retrofitting. One principal suggested that water supply should be enough to make the recovery better, a viewpoint that resonates with the data presented in the next section that there generally was insufficient water for both drinking and handwashing. Figure 4 illustrates principals' identified barriers to complete recovery, the providers of the inadequate solutions, and the principals' recommendations for how to overcome those barriers.

By contrast, as indicated in Figure 4, two-thirds of principals felt that WASH services 3 years after the earthquake *were* sufficiently meeting basic needs, and of these, a half believed that they had an adequate permanent solution. Seven of 15 principals felt that WASH services were the same as before, while four believed that they were now better. Eleven of 15 felt that WASH facilities were now resilient to the cause of the initial damage, and 10 of 15 felt that WASH facilities protected users

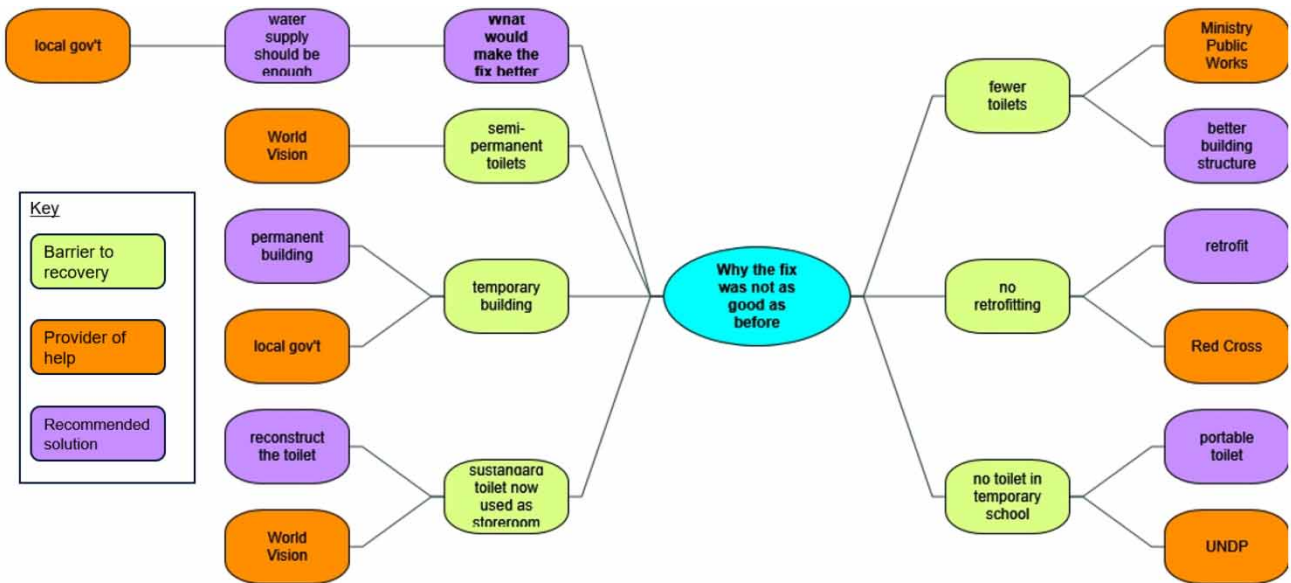


Figure 4 | Principals' perceptions of the barriers to recovery. Source: Principal interviews.

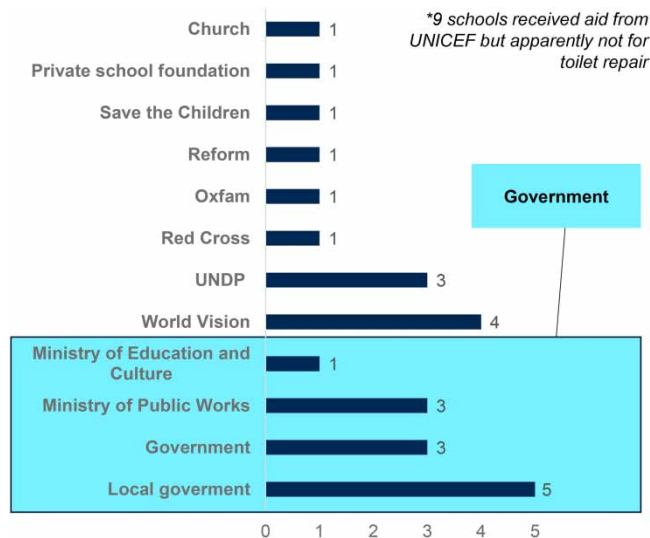



















Figure 5 | Who did the toilet repairs. Source: Principal interviews.

Table 3 | Data disaggregated by hazard zones in which schools were located

A	B	C	D	E	F	G	H	I
Schools in Zones 3, 4	Zones 3, 4 sample size	Schools in zone 2	Zone 2 sample size	Schools in zones 0, 1	Zones 0, 1 sample size	Metric	Submetric	Sparkline graph
						Drinking water		
						<i>Quality</i>		
4	4	3	5	5	5		Drinking water from protected water source (observation)	
4	4	7	7	6	8		Drinking water is not coloured, does not smell, does not have a taste, does not contain pollutants (principals)	
						<i>Quantity</i>		
1	4	3	8	2	9		Reliable drinking water (principals)	
1	5	2	8	2	9		Enough water to meet drinking needs (principals)	
						Handwashing		
						<i>Water</i>		
3	4	4	5	3	3		Water at handwashing station in toilets (observation)	
2	3	5	5	2	4		Water at handwashing station outside toilets (observation)	
2	4	5	8	7	9		No water outages reported (principals)	
1	5	1	8	-	9		Water quality tested (principals)	
						Toilet facilities excluding handwashing		
						<i>Facility cleanliness</i>		
1	4	3	5	-	3		No observed mess around toilet, clogging (observation)	
						<i>Safety from vector-borne diseases</i>		
4	4	3	5	2	4		No mosquitoes observed (observation)	
						<i>Safety and security</i>		
3	4	4	5	3	4		Door locks (observation)	
2	4	3	5	1	5		Adequate lighting (observation)	
3	4	5	5	4	5		Path to toilets not muddy or broken (observation)	
						Rubbish collection and dispensation		
						<i>Environment free from waste</i>		

(Continued.)

Table 3 | Continued

A Schools in Zones 3, 4	B Zones 3, 4 sample size	C Schools in zone 2	D Zone 2 sample size	E Schools in zones 0, 1	F Zones 0, 1 sample size	G Metric	H Submetric	I Sparkline graph
2	2	–	5	1	4	<i>Environmentally friendly waste disposal</i>	Minimal or no rubbish observed on campus (observation)	
2	4	5	5	4	5		Appropriate and adequate waste storage – absence of rubbish heaps (observation)	
2	4	2	8	3	9		Appropriate and adequate waste storage – separation of waste type (principals)	
3	4	5	8	3	9		Appropriate dispensation – no burning of waste (principals)	

Sources: Structured observations and principal interviews.

from transmission of disease. In the following section, we document what our data collection team observed that could be considered to be resilient to damage and what protected or did not protect users from transmission of disease.

External actors who enabled the repair of WASH facilities were cited as a multitude of government and non-government institutions, with the local government, World Vision and UNDP cited most frequently. Twelve principals reported that government entities had done the repairs and 13 principals reported that non-government entities had done the repairs. [Figure 5](#) shows entities that carried out repairs.

3.2. The current WASH situation

This section presents evidence from a combination of structured observations and principal interviews on the existing WASH condition in schools.

1. We split data observations by hazard zones in which schools were located, and by whether schools were state or privately owned, to compare the state in which we found WASH conditions. The hypotheses being tested were that: private schools would offer better WASH facilities, and
2. schools in more hazardous zones would take longer to recover and so have the worst state of WASH facilities,

3.2.1. School WASH facilities by hazard zoning

The sparkline graphs in column H of [Table 3](#) depict the proportion of schools by zone 1 or out of zone (the two safest hazard zones); zone 2; and zones 3 and 4 (the two most dangerous zones) that meet the WASH assessment criterion in column H. These criteria assess potable drinking water access, handwashing facilities, toilet facilities, and rubbish collection and dispensation. The key finding is that there is no consistent pattern discernible across the 17 indicators. For example, schools in zone 2 (not the most dangerous nor the least dangerous) came out looking the best for 6 of 17 indicators and came out looking the worst for two of 17 indicators. Only 2 of the 17 spark line graphs have a monotonic function in the direction that supports the hypothesis that schools in the least hazardous zones have the best WASH facilities.

3.2.2. School WASH facilities by private vs state funding

The results in [Table 4](#) show that out of 25 indicators split across criteria assessing drinking water, handwashing facilities, toilets, and rubbish collection and dispensation, private schools outperformed state schools in 18 of them, i.e. on five more indicators ($25 \text{ indicators} / 2 \text{ types of school} = 12.5 \text{ indicators}$) than would have been expected if private schools and state schools offered no difference in the level of WASH provision service. This is on $1.4\times$ more indicators that private schools outperformed state schools than would have been expected had there been no difference. Private schools outperformed state schools in drinking water quality and quantity; on presence of soap observed at sinks outside toilets (but not inside toilets); on water available at handwashing stations outside of toilets (but not inside toilets); on having fewer than 250 people per working tap; on water quality testing; on the presence of toilet paper; on the presence of sanitary napkins and bins in toilets; on the absence of mess around toilets; on the environment being free from faeces; on having toilet doors lock and having adequate lighting in toilets; on having minimal rubbish observed on campus; on having an absence of rubbish heaps; and of not resorting to burning of waste on campus.

Following are some of the most noteworthy results.

3.2.2.1. Drinking water. Two state school principals (of 23 who responded) perceived drinking water to be unsafe because it was coloured, had an odour, or was perceived to be contaminated. As reported by the principals, the supply of water does not seem compliant with a clean water standard of the Sanitation Guidelines for Schools ([Ministry of Education and Culture 2018](#)). Both principals also reported that students fell sick when they drank the water.

3.2.2.2. Handwashing stations. Principals reported that water was least likely to be running during peak hour usage at 8am, right after the 2018 earthquake and when there were power outages and water tanks were not full. To cope with main water outages, principals of 10 schools reported using water supplied by trucks, gallon water, well water, and one school used river water. Two state schools were found to have hand sanitiser. Several schools have built resilience into their handwash stations by not having all of them connected to the main pipes. From the structured observations, it was found that 9 of 15 schools used water containers, either in addition to (6/15) or instead of piped water (3/15).

Table 4 | Assessment of current WASH status results using sphere metrics

Private schools	Private school sample size	State schools	State school sample size	Metric	Submetric
				Drinking water	
				<i>Quality</i>	
3	3	12	14		Drinking water from protected water source (observation)
4	4	17	19		Drinking water is not coloured, does not smell, does not have a taste, does not contain pollutants (principals)
				<i>Quantity</i>	
4	4	6	21		Reliable drinking water (principals)
4	4	5	22		Enough water to meet drinking needs (principals)
				Handwashing	
				<i>Soap</i>	
0	4	1	13		Soap observed at sinks in toilets (observation)
3	4	6	14		Soap observed at sinks outside toilets (observation)
				<i>Water</i>	
3	4	10	12		Water at handwashing station in toilets (observation)
3	4	9	14		Water at handwashing station outside toilets (observation)
2	4	14	21		No water outages reported (principals)
4	4	7	10		Fewer than 250 people per working tap (observation + principals)
1	4	2	22		Water quality tested (principals)
				Toilet facilities excluding handwashing	
				<i>Anal, vaginal, urethra cleansing</i>	
3	4	11	13		Jug and water or hand bidet (observation)
1	4	0	13		Toilet paper (observation)
				<i>Menstrual hygiene</i>	
1	4	8	21		Sanitary napkins observed or reported as present (principals, observation)
2	4	0	13		Bins (observation)
				<i>Facility cleanliness</i>	
2	4	4	12		No observed mess around toilet, clogging (observation)
4	4	17	18		Environment free from faeces – no sewage residue reported during sewage collection (principals)
				<i>Safety from vector-borne diseases</i>	
2	4	9	13		No mosquitoes observed
				<i>Safety and security</i>	
4	4	10	14		Door locks (observation)
2	4	6	14		Adequate lighting (observation)
3	4	12	14		Path to toilets not muddy or broken (observation)

(Continued.)

Table 4 | Continued

Private schools	Private school sample size	State schools	State school sample size	Metric	Submetric
				Rubbish collection and dispensation	
				<i>Environment free from waste</i>	
1	4	3	14		Minimal or no rubbish observed on campus (observation)
1	4	3	14		Appropriate and adequate waste storage – absence of rubbish heaps (observation)
				<i>Environmentally friendly waste disposal</i>	
1	4	7	21		Appropriate and adequate waste storage – separation of waste type (principals)
4	4	7	21		Appropriate dispensation – no burning of waste (principals)

Sources: Structured observations and principal interviews.

3.2.2.3. *Toilets (excluding handwash stations)*. Most schools' toilets seemed to have been fully restored since 2018. Photographs from the structured observations showed no shattered toilets, and only one school continues to have non-functioning toilets. The presence of mosquitoes was noted in more than half of schools' toilets (11/17). Photographs showed pools of water for toilet washing without lids over them to prevent vector-breeding, and toilets without levered flushes or lids to prevent the entry and exit of mosquitoes and flies.

Bins were missing in most schools' toilets (2/17), let alone bins with lids (0/17). Sanitary napkins were observed to be provided by just one school, though 10 of 25 principals reported that their schools made sanitary napkins available. Eight principals said that their schools did not provide sanitary napkins and had no plans to provide them. In terms of fostering an enabling environment, 14 of 25 school principals reported having teachers trained in menstrual hygiene management, and 7 of 25 principals reported having parents trained in it. To assess user safety and security, we assessed whether the doors can be locked, whether there were light facilities, and whether paths to toilets were unbroken. More than half of toilets lacked sufficient lighting to comfortably see what they were doing according to our data recorders (8/18 were assessed as having adequate lighting). Four of 14 state schools' toilets doors did not lock, and three of 17 schools' paths were broken or muddy.

3.2.2.4. *Rubbish and rubbish collection*. Eight of 25 principals reported that their schools separated waste, and structured observations suggested a similar number of schools separating out waste (in hazardous materials, leftover food, or food packaging). Further, seven principals said that they had plans to introduce separation of waste, and six positively said that they had no plans to introduce separation of waste. Fourteen of 25 principals reported having rubbish burned. Twelve of 24 principals reported that the school paid for rubbish collection. The most popularly cited challenge with rubbish collection was that it was too infrequent.

4. DISCUSSION

The results of the study show that private schools delivered better WASH facilities for students than state schools. In so doing, it adds to a sparse body of literature with limited sample sizes and triangulates with a study of four schools conducted in Ethiopia (Deyasso & Ashenafi 2022). It also aligns with the much more general finding in the literature that private schools often deliver higher quality services than their state counterparts (e.g. James *et al.* 1996; Andrabi *et al.* 2008; Bold *et al.* 2011). It supports the thesis that privately funded schools need to demonstrate value to justify their fees, and that this value can be demonstrated in the form of a better user experience of WASH facilities.

The results do not support the hypothesis that schools located in more hazardous zones had recovered more slowly and therefore offered worse WASH facilities to students, 3 years after the earthquake. The government's 2019 hazard zoning does not appear to have predictive power over the state of WASH conditions at schools.

Kates *et al.* (2006) and Chester *et al.* (2021) suggest that post-disaster reconstruction happens between 2 months and 10 years, and 10 weeks and 950 weeks, respectively, which aligns with the mixed results from our principal surveys. After 3 years, fixes to WASH infrastructure were rated at least as good as they had been before the earthquake in all but in four cases, where school principals reported that recovery was not as good as before the earthquake and that they were still seeking permanent fixes.

Much of the state schools' WASH inadequacy cannot be attributed to the earthquake, since as already noted, most principals assessed that their WASH facilities were as good as before the earthquake, when as noted in the literature, the WASH situation across Indonesia was already lacking: 36% of secondary schools across Indonesia had no handwashing facilities (JMP 2020), demonstrating limitations in enforcing government policy gaps (Ministry of Education & Culture 2018).

There was evidence that schools provided WASH in such a way as to be more resilient to water outages, such as those that were reported by principals when water pipes were damaged in 2018. Many handwash stations were not connected by pipes to water supply from the utility, but rather to their own containers of water. There is a possibility that these were introduced in response to COVID-19, since, for example, UNICEF reported in May 2020 that it had commenced delivering handwashing stations (UNICEF 2020). Buckets and other receptacles of water inside toilets meant that there were often water reserves with which students could wash themselves even when there were water outages.

There is a need to address the inadequate supply of drinking water at many of the state schools visited, including quality of drinking water at two of the schools, and indeed this was one of the recommendations that principals had for improving recovery. Many wash stations lack soap and some lack water. As per government guidelines, schools in Indonesia have to stock bins with lids for the purpose of safe disposal of menstrual waste and required to provide sanitary napkins (Ministry of Education & Culture 2018), and yet most of the visited schools did not meet these required standards.

There is also scope for making WASH infrastructure safe beyond the scope of SDGs 6.1 and 6.2. Unlidded buckets with water near toilets can encourage vector-breeding, as was observed in Colombia by Olano *et al.* (2015) and can lead to vector-borne diseases. The results showed that mosquitoes were observed in most schools' toilets. These can infect schoolchildren with malaria, lead to absences and even impair their cognitive abilities after recovery (Fernando *et al.* 2010). The literature from the Philippines, England, Sweden, and China suggests that WASH inadequacies and that the appearance of unclean toilets can prove to be inhospitable, which can result in reduced toilet use; constipation, urinary tract diseases and incontinence; and negatively affect, particularly, female school attendance and enrolment (Vernon *et al.* 2003; Cas 2016; Shao *et al.* 2021; Garfias Royo *et al.* 2022).

5. LIMITATIONS

Given travel restrictions from the UK to Indonesia and internally within Indonesia due to COVID-19, data collection was limited, and we did not manage to conduct as many observational structured observations as we did principal interviews, or collect a larger sample of private schools. Travel restrictions ensuing from COVID-19 protocols also limited our data collectors' access to schools in Donggala district and skewed data collection towards schools in Palu. However, this had no apparent effect on the distribution of schools across hazard zones. Given the limited number of observations, we used descriptive statistics rather than regression analysis, and sought whether the results supported hypothesis rather than disproved null hypotheses.

Nevertheless, this study did enable us to test the Sphere Humanitarian Framework and collect evidence to assess WASH conditions in a sample of schools in the region.

A further limitation was that our comparison of WASH services before and after the earthquake depended fully on the memories of the school principals whom we interviewed. Retrievability bias may have discounted how bad WASH services were further in the past.

Our study did not investigate what school teams themselves did to facilitate reconstruction, or what the enablers to recovery of WASH services were. These are areas that could be investigated in future studies.

6. CONCLUSIONS

This paper examined how the natural hazard event of 28 September 2018 was perceived by school principals to impact WASH at schools in Central Sulawesi, and to assess the adequacy of the solutions implemented to address the impact, as

perceived by the school principals themselves. It compared WASH adequacy assessments between state and private schools and found that private schools delivered better WASH services to their students. It compared the WASH situation in state schools in different hazard zones and found no discernible difference after 3 years between WASH at state schools exposed to different intensities of hazards, as proxied by their location in different hazard zones. It further found that after 3 years, reconstruction and recovery were not complete at all schools.

We analysed data collected from structured observations and principal interviews through the Sphere Humanitarian Framework to assess WASH adequacy at schools in Central Sulawesi almost 3 years after the 2018 earthquake. Principal interviews enabled a comparison of pre- and post-earthquake WASH services at schools, allowing us to identify barriers to recovery. The results enabled us to assess reconstruction and indicated that much of the inadequacy that was observed on the structured observations was not attributable to the earthquake. WASH researchers and practitioners can use this combination of tools for collecting and analysing school WASH data globally.

Our data show that there is room for improvement in the Central Sulawesi context, despite overall good resilience built into existing WASH facilities. Addressing these deficiencies could prevent the transmission of diseases from unsafe drinking water, through unwashed hands, and transmission by vectors. Further engagement and research by students adds a further understanding regarding their challenges with WASH facilities that are required to query perceptions of their emotional response and experiences, which cannot be gauged alone with structured observations and interviews with school principals. Targeted investment in schools for WASH as part of post-disaster recovery plans could benefit all children, and in particular girls. This will require cross-sectional partnerships between government and non-government agencies and schools with targeted WASH interventions.

AUTHORS CONTRIBUTIONS

H.J., P.P., S.N., and E.M. developed the initial project idea and submitted the ethics forms at their respective institutions and with the relevant Indonesian authorities. E.M. found and translated relevant WASH data for schools in Central Sulawesi. I.A., E.O., and P.P. designed the overall tool and prepared the study design, protocols, and training which were reviewed by E.M., S.N., Y.I., and I.R. and then executed by E.M., S.N., Y.I., and I.R. M.G.R. contributed to the literature review, discussions, and structuring. S.N. supervised the collection of structured observational data. I.A. analysed the data and computed calculations, which M.G.R. and P.P. reviewed. I.A. drafted the paper, which M.G.R., P.P., E.O., S.N., E.M., Y.I., I.R., and H.J. reviewed.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Study details were explained to school principals who were interviewed in the local language Bahasa. Written consent was provided in the official letter from the Education Department to the school principal of every school, after we delivered the letter of permit to survey to the Education Department prior to the fieldwork, and further oral consent was obtained from school principals in Bahasa. People were not photographed. The study was approved by UCL Research Ethics Committee in the UK (0525/001) and in Indonesia (111/EA/FK-RSUDZA/2021).

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.;

CONFLICT OF INTEREST

The authors declare there is no conflict.

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