Improving access to safe drinking water in rural, remote and least-wealthy small islands: non-traditional methods in Chuuk State, Federated States of Micronesia

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Abstract: Western Pacific small island rural communities suffer from waterborne diseases and are among the least wealthy, most remote and resource-poor across the globe. Small landmasses, geologic composition, geographic isolation, a colonial history, and weak educational, technological and financial resources constitute significant barriers to strengthening capacity to access safe drinking water. High-technology, high-cost and complex Northern (Western) models for mitigating water access problems often prove inappropriate and unsustainable. The aim of this paper is to offer a non-traditional approach for improving both sub-national environmental analysis capacity and engaging in low-technology and low-cost mitigation of vulnerability to waterborne disease at the village-scale. The approach involves a combination of techniques, including Geographic Information Systems (GIS) training, basin management, environmental health education at the grassroots scale and working with civil society to support appropriate technologies. The findings improve understanding of remote, rural and least-wealthy small island conditions, offer guidance regarding environmental management in the Western Pacific, and provide insight for developing outreach programmes with the aim of improving conditions on similar islands globally.

Keywords: appropriate technology; Chuuk State; drinking water; environmental education; Federated States of Micronesia; FSM; Geographic Information Systems; GIS; participatory watershed management; small islands; Third World; Western Pacific.

Biographical notes: Dr. William James Smith Jr. focuses his research and teaching at the nexus of environment-technology-society relations. He has an interdisciplinary background, with particular expertise in management of water resources and ‘sustainability’ praxis. His work incorporates a variety of modelling and qualitative techniques, and investigation of underlying causes of changes in relations between humans and the environment utilising political economy and political ecology approaches. In industrialised settings he largely focuses on climate change, and public participation in watershed management to mitigate hazards, protect ecology and support environmental justice. In less-wealthy parts of the world his focus is on improving access to safe drinking water, partnering with local people for participatory conservation and capacity building, geographic information systems, and blending indigenous and outside knowledge to address public health and environmental concerns. He has worked in the Philippines, Micronesia and the USA.

1 Introduction

Although the technology and resources exist to mitigate suffering and death caused by a lack of access to safe drinking water, society as a whole has not satisfactorily addressed the problem. According to data presented by the World Health Organization on global access to proper water and sanitation, over 1 billion people are without safe water; over 3.4 million deaths occur annually due to being without safe water, 2.2 million of which are children and 14 000 to 30 000 die each day from consuming contaminated water or food (Gleick, 1999; United Nations Educational, Scientific and Cultural Organization, 2006; World Health Organization, Water Sanitation and Health, 2006). Globally, as the new millennium approached, 69% of rural areas had access to water and 33% to sanitation (up 8.2% and 6.4% respectively since 1990), with some estimates for what is aggregated as ‘Oceania’ upwards of 90% (United Nations Economic and Social Council, 2000). Due to relatively large population centres in the industrialised part of Oceania, and based on my findings, it can be argued that these numbers do not well represent conditions in Rural, Remote and Least-Wealthy (RRLW) communities.

This paper examines the project management challenges to building water resources management capacity and mitigating vulnerability to unsafe drinking water in the RRLW small islands of Chuuk, Federated States of Micronesia (FSM) in the Western Pacific (Figures 1 and 2). Such communities may be only a few hundred people on small basalt (high) islands or tiny coral atolls surrounded mostly by millions of square kilometres of ocean (Figure 1). RRLW small islands remain impacted by their physical geography and a relative lack of exchange of information and technology with the outside world. This, together with minimal human, economic and natural resources, necessitate strategies that assume almost no technical capacity. Researchers in these isolated island regions require knowledge of local cultures and an eye for appropriate technologies that fit the village-scale in a variety of ways. For example, in terms of economic effectiveness of proposed solutions, their technological complexities, the availability of replacement parts, and appropriateness in relation to culture and sustainability.
Figure 1  Exclusive economic zones of Micronesia
The project carried out in 2002 in Chuuk, involved a combination of geographic information systems applications and training, basin management, environmental health education at the grassroots scale and working with villagers to support appropriate technologies. The project operated primarily at two scales. The first scale revolved around building state level managerial capacity in areas of environmental analysis, technology, water improvement strategies and environmental health outreach. The second scale focused on village/sub-basin level analysis, low technology and low cost source water protection and environmental outreach. Strategies were implemented at both scales simultaneously to allow lessons from the work at each scale to inform the other early enough to make meaningful adjustments. Sub-basin inventories in Chuuk Onongoch, Fogen and Fein villages were carried out through physical and behavioural surveys in 2002. The survey examined point and non-point contaminants, state of technologies in use, sanitation, water collection techniques and consumption. Findings supported the development of an outreach programme for developing sustainable development capacities in Chuuk and other islands with similar problems.

The paper proceeds by discussing Chuuk State, Federated States of Micronesia, a set of RRLW small islands. The section below provides details regarding the physical, biogeographical and cultural geography of Chuuk State. This is followed by sections
covering outreach strategies and technologies, the ‘Pacific Way’, meaning how Pacific
island nations avoid conflicts in such small spaces, and the importance of understanding
the way that indigenous peoples use technology. In particular, the section discusses
issues relating to groundwater, water infrastructure and capacity. This is followed by
discussions regarding capacity and technical needs assessment. The penultimate section
covers GIS techniques, remote sensing, and a sub-basin water inventory.

2 Chuuk State, Federated States of Micronesia

Chuuk State, FSM has a physical, biogeographical, historical and cultural geography
inclusive of the subcultures of the States of Yap, Chuuk, Pohnpei and Kosrae (Figures 1
and 3) (Denoon et al., 1997). The US Department of State (1996) notes landmass to be
699 sq km (270 sq mi) over four major island groups, totalling 607 islands and stretching
2897 km (1800 mi) east to west. Chuuk State possesses a land area of 127 sq km
(49 sq mi) (US Department of the Interior, 1999). Of its 290 islands, 40 are inhabited,
the rest are mainly for food. Island geology and topography vary from relatively large
and ‘high’ mountainous basalt islands, to tiny ‘low’ coral atolls. Weno is the location
of the Chuuk airport, hosts government facilities, contains a small urban centre on
approximately one-third of the island, and is one of Chuuk’s 19 high volcanic islands
enclosed by a coral ring composed of 87 small and low coral islets (Figure 4). See Smith
(2003b) for detailed analysis of the area’s physical and human geography and a brief
history and pre-history of the region. See Hezel (1973), Keating et al. (1984) and Terrell
(1998) for a detailed early and pre-history of the Pacific Islands and Chuuk. The islands
are categorised locally in three groups (Figure 2). First are ‘high islands’, which are
volcanic and are only found in Chuuk Lagoon, second are coral-based ‘reef islands’
(‘low’) of Chuuk Lagoon, and third are coral-based ‘outer islands’ (‘low’) that exist in
extreme isolation up to 12 h by ship outside of Chuuk Lagoon.

Figure 3 Ethnic regions of Oceania

Source: Terrell (1998)
Figure 4  Landsat 7 ETM+ imagery of Chuuk Lagoon illustrates major high islands and Neoch Atoll (coral appears light blue) (20 mi = 32 km) (see online version for colours)

Table 1  Population density for Federated States of Micronesia: 1994 and 2000

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<tr>
<th>Attributes</th>
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<th>2000</th>
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<td></td>
<td>Total</td>
<td>Yap</td>
<td>Chuuk</td>
<td>Pohnpei</td>
<td>Kosrae</td>
<td>Total</td>
<td>Yap</td>
<td>Chuuk</td>
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<td>11 178</td>
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<td>33 692</td>
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Source: Calculated from data from the Division of Statistics, FSM (2002)

Chuuk accounts for 50.1% of FSM’s population, whereas Pohnpei, Yap and Kosrae represent 32.2%, 10.5% and 7.2% respectively (Division of Statistics, FSM, 2002) (Table 1). Chuuk has a strong mariner culture and the population is highly concentrated along the coasts. Temperature varies little in this area, which is approximately 7 degrees
north of the equator, and relative humidity ranges from 55% to 100% (Hamlin and Takasaki, 1996). Data from the National Weather Service (NWS, 2008) at Weno Airport for 1952–1985 indicate the period of January to March brings about half the normal rainfall of 356 cm (140 in) annually (Karolle, 1993).

3 Outreach strategies and technologies

Falkland (1990) provides a thoughtful set of profiles of appropriate water management technologies for small islands. Whyte’s (2001) research on best management practices in the Pacific is an excellent complement to such information because it puts technology implementation in context. Ideally, the minimum criteria for sustainable technology for places like the remote Western Pacific includes:

- ability to withstand weather conditions that cause rapid degradation
- easy to maintain using only local talent
- educational component must support implementation
- effective enough to warrant utilisation, even if not ‘efficient’ by northern standards
- is going to serve all ages, the disabled, gender and economic classes relatively well
- not likely to create local conflict or set-off other environmental health problems (e.g., increasing vector-borne diseases)
- not likely to create unacceptable opportunity costs (e.g., no money for books)
- scaled to fit demand and physical setting, as opposed to scaled at a factory-set scale
- simple enough to be widely understood and locally valued
- utilises cheap local, or widely available, materials for maintenance and upgrades.

There is also a question of equity in terms of spatial distribution of technology. If each time funds are available to pursue water improvement a typical centralised high-technology and high-cost system is favoured, the project will likely gravitate to the most wealthy population and influential part of a relatively powerful island, often one with government officials and tourists in a relatively urbanised setting (e.g., Weno). Even if a system runs well in the area of concentrated capital, expertise, and political ‘clout’, this is still not acceptable. This uneven approach may violate the human right to water, in terms of distributional equity, as defined by the United Nations Economic and Social Council (2002). Decentralised, sustainable, low technology and low-cost approaches to water and sanitation like those favoured by the ‘WASH’ (Water Supply & Sanitation Collaborative Council, 2006), ‘SAFE WATER’ (Centers for Disease Control and Prevention and CARE Health Initiative, 2008) and ‘PHAST’ programmes (World Health Organization, Water Sanitation and Health, 1998) should be considered.
4 The hidden nature of ‘low-cost’ approaches and the Pacific way

Low-technology/Low-cost approaches to water supply improvements may incur a high ‘cost’ in terms of community effort and sacrifice (Whyte, 2001; White and Bradley, 1972; 2001; Winter and Stephenson, 1981). For example, altering the locations of point and non-point pollution sources so that they are lower in a basin and below water intakes may cost little money. The creation of vegetation buffers to filter runoff is also ‘low-technology’. This type of approach requires significant amounts of time and may be set against local traditions. Obtaining permission for access to private and common land, coordinating local labour and adapting projects to local community priorities are not insurmountable issues, but provide challenging hurdles.

Input from local partners in villages, rather than from the country, region, or state scale is important to avoid conflicts that could occur regarding the use of land where the technology must be placed (Winter, 2000). Any infrastructure, plant or equipment installed that are not truly accepted locally will perhaps result in the technology being torn down or at least neglected. Having local partners also helps to cope with unhelpful views of the national government, as perhaps would forming a Non-Governmental Organization (NGO).

The ‘Pacific Way’ is a term and a social standard used to describe how Pacific small island cultures try to avoid numerous conflicts. Marshall (1979; 2004), one of a handful of researchers to work in multiple locations in Chuuk, has discussed the role of the ‘Pacific Way’. Disregarding this accepted social standard, disrespecting community voices and ignoring the Pacific Way can set-off reactions that are difficult for outsiders to anticipate. Understanding indigenous uses of technology is also important for avoiding conflicts (Stephenson and Kurashina, 1983; Shutler et al., 1984; Hunter-Anderson, 1987; Winter, 1987). Showing respect for a local leader, historically the Melanesian ‘big-man’, the Polynesian Chief, or Pohnpei’s Soumas and Nahnmwarki, etc., in the FSM through the way one approaches, and works with, a particular village is important in attempting to introduce new technological applications or natural resource regimes.

4.1 Local culture, politics and unexpected barriers to technology

Understanding local politics is essential for avoiding unexpected ‘barriers’ to outsiders. Winter and Stephenson (1981), noted, for example, how dating habits and jealousy ruined water improvement projects in the Western Pacific on a number of occasions. In one instance the steps required to improve water availability were relatively simple. It required the installation of plastic pipes from the source to a point in the village. According to Winter and Stephenson (1981), travelling into the high island’s interior for water had traditionally provided an opportunity for young people socialising and courting. The young men reacted to the intrusion on their culture by hacking up the installed pipes. In another case, PVC pipes ran across a small section of a villager’s land but did not provide the owner a connection. The neglected stakeholder gathered dried coconut shells and set fire around the pipes. Perhaps arranging a form of contract with communities ahead of time would be helpful to avoid such conflicts and cultural impositions. However, determining how many signatures would constitute ‘consensus’ would be difficult. This is especially true if indigenous political hierarchies have become weak in the face of globalisation.
5 Findings: water resources, capacity, quality and health

5.1 Ground water

Water yield on high islands is variable depending upon method of collection. Compacted volcanic material results in a shallow (unconfined) ground water lens (Anthony et al., 1993; Takasaki, 1989). Thus, what occurred on the surface of the land rapidly impacts groundwater quality. This is one reason that rooftop catchments are attractive, especially since the area experiences large amounts of precipitation. However, I found that shallow wells and springs that villagers dug out by hand were often used (Figures 5 and 6). Protecting water for consumption through sustainable sub-catchment management practices should be a priority, and I wonder if a demonstration site of ‘best practices’ would have great value.

Figure 5 (a) PVC drains from stream with rocks holding pipe in dug-out bed and forming a small check dam, (b) PVC drains to tank at interview site F02, (c) PVC drains from covered spring hole at interview site F04 (see online version for colours)

Figure 6 Interview site F09 with separated systems (see online version for colours)
5.2 Water infrastructure

Most housing units across the FSM were built between 1988 and 2000. Modern water delivery (of questionable quality) was only found on a portion of Weno (Cowan, 1982). Piped water came to the relatively built-up area near the state government and small tourist infrastructure. Another system existed on Tonowas, but political concerns over territory removed it. The few hotels on Western Weno had their own water treatment systems. There was a limited sewage collection network, but no treatment facilities, as waste was piped into the lagoon raw for ‘mixing’ near the airstrip. Electricity was selectively available on Weno, but power was periodically lost due to failure of technology and government not paying its bills.

5.3 Capacity

Daily life in most of Chuuk is run on an extended family scale, with village or island functions superimposed on top of this routine. National and state levels of government do not have sustained and strong influence in most aspects of daily life. In such a weak ‘regulatory environment,’ and with the traditional forms of environmental management across the FSM weakened by contact with the outside, there is arguably a leadership gap that needed filling (Hezel, 1973; McEvedy, 1998).

Environmental analysis and management capacity is poor. Technical needs assessment, strategic purchasing and maintenance, supplies, training and preparation of trainers, as well as oversight of application in the field, are lacking. For example, the Chuuk State Environmental Protection Agency had no mapping capacity (before this research) or functioning water quality lab (we initially had hopes to address this), and only a few staff located only on Weno for the entire state. In addition, telephone, fax, internet and electricity are often non-operational, or in jeopardy of being so due to lack of funds. Environmental education at the grade and limited ‘college’ levels was unsupported.

6 Environmental health and water quality

A few studies of water quality and resource management have been conducted in Chuuk in the past, mostly on Weno, with many around 20 years old (Clayshulte and Zolan, 1980; Clayshulte, 1983; DeWolfe et al., 1991). Fontaine (1987) found that unsafe water was a primary cause of FSM’s poor public health. In FSM, greater than 30% of all diseases were directly connected to inadequate access to safe water. For example, Pohnpei, Chuuk’s neighbour, experienced a cholera outbreak in 2000. Close to 3000 were hospitalised, and at least 21 deaths were recorded (Khosrowpanah and Heitz, 2003). In the 1980s Chuuk experienced a cholera outbreak that the US government assisted its former Trust Territory in coping with through construction of rooftop catchments, many of which fell into disrepair. The FSM/UN group (1995) pointed out that not only was safe water important, but diseases known as ‘waterwashed’ diseases can be caused by a lack of water for basic hygiene and hydration. The same literature noted that hospital records showed that 20% of patients in 1993 and 1994 had diseases that were caused by either poor water quality or insufficient water. Also reported were very high levels of total and fecal coliforms in source water.
Improving access to safe drinking water

7 Applying GIS techniques

Land use and land cover affects water quality, especially in areas like Chuuk, where sources of water for consumption are either at the surface or very near it. Understanding land cover and land use, and also where water is captured relative to potential sources of pollution such as dumps, areas of concentrated human or other animal waste, or heavy erosion, is important in planning for basin management in support of source water protection for consumption. The use of GIS in combination with Remote Sensing (RS), utilising high resolution satellite imagery donated, provided important tools for analysing, storing data about, and managing land and water in the FSM. There is potential for GIS and RS to improve understanding of what is occurring on the land so that it can be better managed, or, at least, potential concerns can be tracked for future management as long-term technological capacity is built – thus, potentially improving water quality.

Some RRLW small islands like Chuuk, FSM have lagged behind in terms of development of baseline GIS data and fundamental applications. Because of these gaps we developed the first GIS and Global Positioning System (GPS) data and training for Chuuk so as to begin to address the issues above (Britton, 2000; Craig et al., 2002; Kyem, 2004). To prepare for outreach regarding waterborne diseases the first basic spatial data layers were created and staff were trained in basic GIS and GPS skills over several visits. We found that it was important to use local examples for GIS/GPS training whenever possible, and to keep a healthy balance between field work and desktop work, along with a very flexible schedule, because it made ideas ‘stick’ and training an enjoyable experience.

Basins were delineated from ‘rim to the reef’ in the ancient Hawaiian Ahupua’a tradition (Project Ahupua’a, 2008). Land cover and land use for the high islands was derived from 4 m (13 ft) colour and 1 m (3 ft) panchromatic IKONOS satellite data. Landsat 7 ETM+ imagery was also used for land cover and for mapping reefs for all of Chuuk State. The mapping process took approximately 1000 h, while time in Chuuk interviewing, training and performing outreach took five trips for a few weeks at a time over 18 months.

8 Sub-basin inventory in Onongoch, Fogen and Fein villages

The following represents our GPS-based source water inventory of the sub-basin including parts of Onongoch, Fongen and Fein Villages in Northwest Fefan (Figure 4). While it is not the hub of the islands, Fefan was selected in part because it was home to one of our partners, who could facilitate good relations, it was well populated, and its land use and land cover seemed a fair representation of what was found on most islands. It was also reasonably accessible by boat from the main island of Weno, at which the Chuuk Environmental Protection Agency and the research team were based.
This research agenda was:

Day 1  Survey and at the same time collect GPS data for mapping of the survey location, source water, potential contaminants.

Day 2  Interview and at the same time collect GPS data for mapping of culturally important places, consumption behaviour, secondary and unmapped tributaries.

The study area had a perimeter of 4281 m (2.66 mi) and an area of 0.96 sq km (0.37 sq mi) (Figures 7 and 8). The population lived in a mostly forested basin, with the exception of the coastal area, wherein occurred the highest population density. Again, the geology is of volcanic origin, providing for a shallow ground water lens that was thin and unconfined, and therefore under fairly direct influence of activities on the landscape.

**Figure 7**  (a) Northern view of Fefan from Southern Weno, (b) Northwest coast including study area of the Island of Fefan, (c) Study basin including villages of Onongoch, Fein and Fogen, (d) Study basin home (see online version for colours)
8.1 Inventory of point and non-point contaminants

An inventory of point and non-point contaminants is typically a core component of a source water protection plan. Those surveyed here are labelled ‘F#’.

The team also planned to arrange water quality monitoring, but a massive typhoon stranded a member long enough to obviate these plans for that time period. An intriguing idea is to develop a customised relatively low-cost and low-technology sampling regime and interpolate from points of data in fresh water and along the shore (especially where tributaries empty). Though it is beyond the scope of this manuscript, it would be interesting to combine the lessons learned here with those provided by The Sanitation Park Project (Bower et al., 2005). This self-described ‘genuinely grassroots undertaking’ is designed to provide regional and Fijian community support by examining and selecting from a range of appropriate, affordable wastewater sanitation treatment methods and technologies. The park is also used for raising awareness and training. Could the same be done for sub-catchment arrangements of sources of pollution and water collection, and low-cost and relatively simple technologies to enhance access to safe drinking water?

There is not enough space to convey all results, so representative findings are shared below. It is noteworthy, that in previous studies on Weno by Detay et al. (1989), that all wells were found to have total and fecal coliform bacteria contamination. This is expected, as we found pig cages next to and spanning streams, and human untreated
waste in close proximity. Our inventories and surveys in Fefan were conducted on a household basis, asking questions and mapping observations, while exploring potential indicators of susceptibility to waterborne diseases such as pollutants, as well as technology and indigenous and newer methods for managing water.

8.2 State of technology

Infectious disease, especially cholera, is a concern. F03, 04, 05, 06, 07 and 08 all recall cholera episodes in the 1980s which led the USA to take action in its then Trust Territory to mitigate the threat through construction of rooftop catchment systems in some places. Education for local maintenance and construction, as well as for coping with growth in population appears unaccounted for, so the sustainability of these systems is severely jeopardised. As is evident by the case of F08, they can degrade. Thus, it is important to consider whether the damaged system can introduce harmful elements to the water, especially given assumptions that such systems provide the most consistently ‘safe’ water (Winter, 1983). It appears that, at a minimum, disrepair encourages use of less safe sources of water such as streams or springs, either alone, or combined with rooftop water in tanks.

When considering what to do in response to such concerns it is worth noting that there are times when practices such as the well-intentioned provision of ‘technical aid’ can lead to unsustainable technology and an increase waste hazards. Examples include the number of abandoned water tanks in Chuuk, and the disintegrating transformers from the power plant on Weno buried just uphill from root crops. Water containers must be safe to use, yet F03 had a 55-gallon tank that was previously used for another purpose, possibly a military relic. This finding deserves follow-up, because, at least theoretically, tanks that once held chemicals could potentially be in use.

8.3 Sanitation

Sanitation varies, as F01, 03, 04, 05, 06, 07, 08 utilise ‘water sealed toilets’ likely connecting to the shallow lens. F03 is rare in that it has a toilet inside, which is convenient, though perhaps less sanitary. At F05 the mud from tropical storm Chata’an (the Chamorro word for ‘rainy’, which occurred 1–3 July 2002) filled in the original metal drum waste repository, and not all had drums. Thus, during storm events it is worth considering whether overflow could mobilise waste products upward so they runoff into streams and water intakes. It seemed wise to advise disconnecting PVC pipes carrying water from streams to storage tanks during and after large events until runoff diminished. Similar concerns existed for F02, where the facility was an overland type of toilet, no flushing and no water seal, forming a cesspool.

F09, a relatively elaborate site, utilised a water closet connected to a septic tank. Waste flowed through a pipe by gravity, down a small gradient to a septic tank within about 24.4 m (80 ft) of a stream that passes upstream, alongside and below the tank. There is no equipment for pumping-out septic tanks on Fefan, and this location is obviously problematic, especially as the tank fills up. The stream is so near the coastline that no neighbour below has PVC water intakes that will be impacted, but contact with waste while swimming in the coastal waters, or through consumption of marine products, is a concern.
8.4 Collection techniques

Community water collection has been altered in RRWL communities since early times (Winter, 1987; Hunter-Anderson, 1987). Techniques evolved from travelling to streams to eat and drink at the source, or to collect water to bring home, to using the trunk of a banana tree like a pipe, to individuals carrying small home made containers, and eventually to using PVC pipes for direct delivery from sources to homes. Water is gathered by pipe from streams or at springs that are at times dug-out by hand and lined with rocks (for ‘protection’ from pollution) and a loose metal cover (Figure 7). In some cases, rooftop catchments are used, but at homes such as F08 the system is broken and raw stream water is combined with any rooftop water available (F08). It is worth noting that Dillaha and Zolan (1985) found fecal contamination in ‘many catchments’ in their Micronesian survey, and that only 38% of those surveyed followed the recommendations to disinfection of rooftop catchment water. Winter (1983) stated that the Water and Environmental Research Institute of the Western Pacific found 25% of its samples failed fecal coliform standards.

F09 utilises a fibreglass rooftop catchment outside. It contained 100% rainwater for drinking, with another concrete tank inside in a screened-in area that is 100% rainwater, but in case of impending or already occurring drought it can connect to a stream-fed pipe to fill up (Van der Burg, 1986). Also, another tank stores stream water for non-consumptive purposes. The sanitary area is downhill and away from the water supply. This was clearly the finest example of micro or family-scale planning to mitigate contamination and also prepared for drought. This represents a potential model to build on, as if all places in the study area maintained the same type of system vulnerability from waterborne and waterwashed diseases would be reduced.

F08 also utilised a system of rain and stream water, but they are always blended. This home utilised piping from a stream to a shower area, with no shower tank, and a fibreglass tank for consumption. The tank received water from a rooftop catchment but it was found to be severely damaged and corroded. In this example, ‘safe’ water was combined with polluted water. Despite this, there was undue confidence in the quality of the water in the home that was not warranted. Here rooftop technology had not reduced vulnerability.

It was observed that leaks in the delivery system were typically dealt with by merely piling relatively large rocks over the top of holes. It appeared that some villagers made an effort to run pipes high up the stream channels, splitting them off when necessary. A leak in a pipe running down land where animal or human waste exists can allow pollution to flow directly to communities from storm water. A low-technology approach may be to provide help in using rocks to raising pipes above ground level.

8.5 Consumption

Water was not boiled before storage in larger tanks, and therefore should be boiled before storage in smaller containers such as pots (F05) and Igloo coolers (F02). The key is that the water should be boiled between storage and use for drinking, cooking, food preparation, and brushing teeth (which is sometimes done in Chuuk while bathing using untreated water). The surveys proved that this is often not the case in the study area. Respondents used the same sources of water for drinking, cooking, food preparation,
brushing teeth and non-consumptive purposes in the majority of cases, be it from a stream, spring or rooftop source. The ‘safer’ water is not separated and saved for meeting basic consumption needs, as would be efficient.

An exception to this assertion, F09 used its intelligent, but low-technology and low-cost, arrangement for reducing vulnerability by conserving rainwater for drinking, cooking, food preparation, and brushing teeth, while spring water is used for bathing and washing clothes. With an annual precipitation of 356 cm (140 in) of rain, reasonably distributed in non-drought years, the system functions well. However, F01 is an example in the opposite direction, as the respondents only ‘sometimes’ boiled their water before drinking, and not for other purposes. Here is a clear example of a group consuming untreated stream water.

Local food preparation, such as preparing taro in a way that requires adding water in the process, or washing vegetables or sashimi, can introduce unsafe water. Thus, whether water is boiled or not before incorporating it in food preparation can impact vulnerability. It appears that no respondents treated water for this consistently. Though, F02 boiled the water it uses when preparing sashimi (raw fish), and F04 preferred to use water from the spring instead of its outside storage tank for this because the residents say ‘its better’. F01, 03 and 05 ‘sometimes’ boiled water for this purpose.

Brushing of teeth can obviously involve swallowing of water and cutting gums if there is enough irritation. However, while F09 used rain water that is not boiled, and F02 claimed to use boiled water for that purpose, F01, 04, 05, 06 and 07 said that they sometimes use treated water, while F08 and 03 indicate they do not.

Treatment in the study area consists only of boiling. To our knowledge there was no chlorination, iodine, filter using native sand, etc., used. However, tanks were cleaned in some cases ‘when needed’. Perhaps it should not be assumed that chlorination would be appropriate until the possible detrimental effects of trihalomethanes, perhaps caused by using chlorine in turbid stream water, are explored. Though it is debatable if this is worthy of consideration given potentially more immediate threats. However, it seems important to provide tank cleaning and hygiene products at a very low-cost and to a large portion of the population, as well as disinfection tablets for use during emergencies.

8.6 Discussion: developing an outreach programme

Given this plethora of complex and varied on-the-ground scenarios, a simple set of guidelines regarding risks from sources of water that are categorised by pollutant can be useful for stakeholders in a brochure form (some laminated due to the humid climate). The written outreach we provided in the local language was based upon the aforementioned surveys of village experiences, sources of water and contamination, and studies of local technology. It is based on observed sources of water and contamination, and ways to collect, treat and store water for consumption. It details the best local sources and treatment options based on a realistic evaluation of resources present, and makes clear which choices are best by categorising in simple language what is risky, least risky, etc. (Table 2). Not included here is the opposite side of the laminated brochure, which uses local examples and subheadings to address questions such as:

- What is a basin?
- Why should I care?
- Can I make my water safer to consume?
<table>
<thead>
<tr>
<th>Techniques</th>
<th>Animal waste</th>
<th>Detergent</th>
<th>Dirt/Erosion</th>
<th>Hazardous household waste</th>
<th>Human waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooftop catchment water kept only, with a clean system and container</td>
<td>No risk</td>
<td>No risk</td>
<td>No risk</td>
<td>No risk if system is clean</td>
<td>No risk</td>
</tr>
<tr>
<td>When boiled and stored and served in a clean container</td>
<td>No risk</td>
<td>No risk</td>
<td>No risk</td>
<td>No risk if system is clean</td>
<td>No risk</td>
</tr>
<tr>
<td>Rooftop catchment combined with spring water in the same tank</td>
<td>Sometimes risky</td>
<td>Little risk</td>
<td>Little risk</td>
<td>Little risk</td>
<td>Sometimes risky</td>
</tr>
<tr>
<td>When boiled and stored and served in a clean container</td>
<td>No risk</td>
<td>Little risk</td>
<td>No risk</td>
<td>Little risk</td>
<td>No risk</td>
</tr>
<tr>
<td>Rooftop catchment combined with stream water in the same tank</td>
<td>Risky</td>
<td>Risky</td>
<td>Risky</td>
<td>Risky</td>
<td>Risky</td>
</tr>
<tr>
<td>When boiled and stored and served in a clean container</td>
<td>No risk</td>
<td>Risky</td>
<td>No risk</td>
<td>Risky</td>
<td>No risk</td>
</tr>
<tr>
<td>PVC pipe bringing water from spring with a vegetation buffer and cover</td>
<td>Sometimes risky</td>
<td>Little risk</td>
<td>Little risk</td>
<td>Little risk</td>
<td>Sometimes risky</td>
</tr>
<tr>
<td>When boiled and stored and served in a clean container</td>
<td>No risk</td>
<td>Little risk</td>
<td>No risk</td>
<td>Little risk</td>
<td>No risk</td>
</tr>
<tr>
<td>PVC pipe bringing water from streams</td>
<td>Risky</td>
<td>Risky</td>
<td>Risky</td>
<td>Risky</td>
<td>Risky</td>
</tr>
<tr>
<td>When boiled and stored and served in a clean container</td>
<td>No risk</td>
<td>Risky</td>
<td>No risk</td>
<td>Risky</td>
<td>No risk</td>
</tr>
<tr>
<td>Drinking water at springs directly without any treatment</td>
<td>Risky&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Little risk</td>
<td>Little risk</td>
<td>Little risk</td>
<td>Risky</td>
</tr>
<tr>
<td>Drinking water at streams directly without any treatment</td>
<td>Extremely risky</td>
<td>Risky</td>
<td>Very risky</td>
<td>Risky</td>
<td>Extremely risky&lt;sup&gt;ae&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Notes:

<sup>a</sup> Boiling will kill germs in dirt, but leave the soil itself, but it is difficult to predict the effect of boiling on reducing a variety of household wastes and detergent.

<sup>b</sup> Under the ‘animal’ and ‘human’ waste categories reduced travel time for pathogenic microorganisms is assumed to increase risk; this is in comparison to water that is piped and then stored before use.

<sup>c</sup> Springs are assumed to be less vulnerable to the second, third and fourth categories due to no ‘upstream’ use and a vegetation buffer (though the fresh water lens is thin).

<sup>d</sup> No technique is safe and avoids risk if good hygiene such as washing dirty hands with soap and water is not practiced when handling water before using it, and the container it is placed in must be clean.

<sup>e</sup> Boiling all water for drinking, cooking, food preparation and brushing teeth, even rooftop catchment water, is the safest strategy, as it will kill microorganisms in the distribution system and storage tank.
A list of ‘DOs’ and a just a few ‘DO NOTs’ are presented in a positive and simple language based on our observations of behaviours, water, pollutants and technologies.

The materials have been produced in a volume and a format that allowed them to be used for hands-on classroom instruction or community workshops (Gundry and Heberlein, 1984). Our concept was to create a simple set of sustainable choices that were flexible to the diverse set of circumstances on the ground, rather than insisting, unrealistically, that everyone obtain the ‘best’ technology. In this way, everyone can maximise their own options, and no one was neglected through focusing on who can afford the superior technology (though best practices to strive for are shared). In addition, this approach took into account the on-the-ground experiences of people, and made use of local knowledge, rather than simply replacing it with outside expertise and advice. The team packaged our community brochures aimed at mitigating risk to unsafe water with a set of posters created in both English and Chuukese for schools and community workshops (e-mail the author for copies).

For those unfamiliar with how to conduct training and workshops Niedermeyer (1992) offers an accessible generic methodology for critiquing environmental education. Cartoons, games, pictures (for those not literate), and posters using local examples do not represent ‘cutting-edge science’, but they may be more appropriate for building capacity to manage resources in such a setting (Winter and Campbell, 1995; Mejia-Restrepo, 2002). The first poster was a general land-water and environmental health poster created for use by local Chuuk EPA and civil society team members for a wide variety of environmental education outreach programmes. Based on our research, it contained general suggestions for land management to guard environmental health, and flexible guidelines for treatment, storage and consumption of water are illustrated. This poster was also of interest to Chuukese people because it contained the first images publicly displayed of the outer islands. For many, even seeing just the lagoon at this scale was a new experience, and curiosity drew people in. A shared basin identity was stressed and underscored the idea of shared resources (Neville, 1999; Sanger, 1997).

A second poster was created specifically for the study area; although it represented a typical Chuukese sub-basin, and therefore, should be useful in other places in the FSM and regionally. This poster combined basin-oriented education for the study area, specific recommended land management practices based on what was learned from the previous surveys, and the flexible guidelines for treatment, storage and consumption of water mentioned earlier. The message was positive whenever possible, avoiding long lists telling people what not to do.

The team used outputs to conduct workshops in communities and for meetings with both students and teachers. We arranged to have meetings at schools in place of end of the day classes. Students and teachers were briefed as to who was on the team and why our work might be considered important to the community. We then met the audience, reinforced our purpose and illustrated some of the more important concepts regarding low-technology and low-cost ways to mitigate vulnerability to waterborne disease using our visual aids. We used posters because of technological limitations and no electricity for the partially enclosed outside area which held a large audience. We held an intensive question and answer session that dominated the time we spent. It was somewhat surprising to me that two of the responses were somewhat hostile in tone and gesture. The first grievance was that we had not done this work before, as we said that the community had been susceptible to waterborne diseases for some time. Second, we were asked why we did the work in one place, rather than in the audience member’s home area.
Nevertheless, communication seemed to go fairly well, and it seemed that at least much of the adult audience understood the key messages. I felt that perhaps the pictures of the watershed from the ocean communicated better to this audience than did the GIS delineations of basins over satellite imagery (Smith, 2003a).

Clearly, both students and teachers were drawn-in by the posters and the images of islands, local people and technologies that were on them. Posters seemed an excellent way to get people of all ages to explore the issues that were of concern. We left laminated versions of all outreach materials at the workshops for teachers to use. Laminated versions of the materials were also hung in public places, while non-laminated versions were donated after workshops for indoor use. The team also presented our work to the Governor, who has displayed them in the main waiting room to his offices to share them with other officials, which may also raise the profile of the work.

8.7 Medium-term strategy for the future

The partners in this endeavour established a research plan for Chuuk, which has been laid out in five stages, the first two of which were completed:

Stage 1  Feasibility pre-interviews with over 30 regional academicians and environmental managers.

Stage 2  Creation of basic spatial data. Establishing fundamental basin management and GIS/GPS capacity for outreach at state-scale, while simultaneously initiating surveys, partnerships, workshops, and environmental health education at the village-scale.

Stage 3  Establishing simplified, geocoded, and low-cost baseline water quality data collection, and creating a monitoring lab and training system appropriate to physical and economic setting (based on our findings it will be best to focus primarily on fecal coliform and household hazardous waste related to energy).

Stage 4  Collaborating for sub-basin land use improvements for source water protection at the village-scale, and implementing appropriate technology with continued environmental health education. Monitoring to quantify changes.

Stage 5  Sharing findings with similar islands, and academic and policy communities.

9 Summary

Our field research reveals a need for a greater focus on sub-basin and village-scale spatial analysis capacity, environmental health education, participatory sub-catchment-level source water protection, and the maintenance and construction of rooftop catchments and other ‘appropriate technologies’. It appears that this scale and these subjects are key for improving access to safe water in a sustainable manner in such settings. Given local constraints, it is possible to address some of the factors making populations vulnerable in low-technology and low-cost ways, but only through participatory methods will changes be sustainable, as federal and state legislation and regulation has little influence over village-scale governance. High-technology, centralised, expensive and
complicated methods and technologies do not offer a solution. Communication must be easily digested, use local examples and integrate local people’s concerns, even if they are not science-oriented.

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References


Improving access to safe drinking water


