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CHALLENGES IN MAINTAINING SUSTAINABILITY OF DRINKING WATER SYSTEMS – AFTERMATH OF A NATURAL DISASTER

Bilal Javed

Author Details (optional)
Bilal Javed is currently working with the Water Globasl Practice of World Bank in Pakistan and supporting in planning, design and implementation of large-scale water supply and sanitation projects. PH: 0092 332 939 1005. E-mail: bilaljavedkhan@gmail.com

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ABSTRACT

October 8, 2005 earthquake was a major calamity affecting the northern regions of Pakistan disturbing the social system generally and drinking water supply systems specifically. In response several organizations of national and international backgrounds intervened the affected areas contributing in different areas including water supply systems.

The current study assessed over eight hundred (800) water supply systems in Northern Pakistan. The water system were either rehabilitated or re-established during the humanitarian response in the study area. New sources were developed succeeding the known principle of build back better in emergencies.

Source displacement in case of spring sources due to variation in tectonic plates left behind the only alternative for the intervening agencies; the surface water source. Sources were developed on surface water (nearly 60% of the new developed sources). The newly developed sources within a limited duration of six years are showing the signs of decay (more than 95% of the sources). The interventions on transitory basis fulfilled drinking water needs but will be a major setback in achievement of SDGs for safe drinking water for the area. The findings from the study suggest that the emergency response should only focus on life saving activities, while disregarding the long term planning areas of emergency stricken areas. Responding to issues requiring long term planning and comprehensive actions during the emergency response stage with projects of shorter duration can lead to long term problems for the concerned government line agencies that at a later stage necessitate even a greater rehabilitation and recovery effort.

INTRODUCTION

October 8, 2005 earthquake was a major catastrophe the South Asian region faced in recent years. The calamity disturbed the entire social setup of the affected areas in Pakistan, Independent State of Jammu and Kashmir and Indian occupied Kashmir. Affected districts in Khyber Pakhtunkhwa (KP) of Pakistan displayed the most alarming statistics regarding life and infrastructure damages.

In response to the catastrophe government and non-government agencies from national and international backgrounds involved in the quake affected districts practicing lifesaving activities initially and infrastructure development measures in later days.

The overall estimated water supply coverage before the earthquake was 50% of the total population of 500,000 households in five Districts of KP damaged by the earthquake, covering about 250,000 households (including 180,000 households with house to house connections). As a result of the earthquake an estimated 77,500 households had only partial or no water supply. The figure does not include the 250,000 households that did not have a water source within a reasonable limit of their house (500 meters) even before the earthquake. Overall damage to the 763 large schemes (average 300 households per scheme) operated by the Water and Sanitation Department, includes 220 that were partially damaged (minor to major repair). Out of the 3,323 small community or TMA operated schemes (hand pumps and small gravity schemes – average 20 households per scheme) 1,234 were partially damaged while 2,089 were operational. The overall estimated cost of these damages to both public utility and community maintained schemes was Rs. 482 million (GoP/EAD, 2006).

Rehabilitation focusing Source Development

The quake affected drinking water systems were rehabilitated with a rapid pace following the principle of *build back better* in emergencies, by numerous humanitarian agencies mostly without coordinating the government line agencies and service providers (ReliefWeb, 2006). Out of numerous challenges faced by the rehabilitating agencies in rehabilitating the existing systems was source displacement, especially in case of spring sources due to variations in the tectonic plates. The existing sources either dried out or their discharge was trimmed down to a significant level. Most of the affected areas were located on hilly terrains and were dependent on gravity based systems mostly based on spring sources (85% of the total) before earthquake (GoP/EAD, 2005). Meager idea of location of alternate water sources and shorter project duration in most left no choice for the agencies working to rehabilitate the systems but to look for alternate sources. Sources were rapidly identified and developed with a considerable number of schemes dependent on surface water.

Agencies intervening in Water and Sanitation sector utilized multiple designs to re-develop or re-habilitate the existing sources for the water supply systems. Structures like cutoff walls, retaining walls and spring boxes were developed on the source points. Due to swift pace of work in adversity and short duration of recovery period along with some very good engineering practices some cases of unsafe and unimproved source development also occurred. The global experiences like 2012–13 Maban County refugee crisis in South Sudan, also provide evidence of transitory planning of water supply planning under emergency situations (ELRHA/HIF, 2016).

Improper engineering at some of the sites distributed the water sources into two broad categories improved and unimproved sources. Improved sources are defined as the *"sources serving a water supply system with a proper engineering structure on the source point designed as per the site and beneficiary requirement while also keeping away the environmental hazards and contaminants"* (UNICEF/WHO, 2017). Unimproved sources lacked either one or all of a proper engineering structure, i.e. appropriate design, size and implementation site.

Inapt source development - Health Impacts

Contaminated water is linked to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio. Inadequate or inappropriately managed water services expose individuals to preventable health risks (WHO, 2018). Inappropriately planned, constructed and managed water systems pose threat to spread of water-borne diseases (Loucks & Beek, 2017). According to the statistics issued by WHO, contaminated drinking water is estimated to cause 502,000 diarrheal deaths each year around the globe (WHO, 2018).

OBJECTIVES OF THE STUDY

The study attempted to explore the key reasons behind the degenerating water supply systems in norther Pakistan by probing into the:

1. Technical design of the drinking water sources developed post-emergency;
2. Sanitary condition of the source points;
3. Key water quality parameters of the water available at the source points.

METHODOLOGY

The study was carried out using standard formats formulated in line with World Health Organization's standards (WHO, 2011) to assess the condition of source points of drinking water supply systems. Since the completeness of the evaluation required access to a variety of information and that too from different aspects, (such as technical information, information based on observations and inspections etc.) a mixed method approach, consisting of quantitative and qualitative data collection tools, was employed as explained:

Sample Size

A total of eight hundred (800) water supply systems in three earthquake affected districts were selected for the study using stratified random selection procedure representing both new and rehabilitated water supply systems. The sample distribution of villages by district for the study is presented in the Table 1 below.

Table 1: Distribution of Sample Schemes for the Study by District

S. No.	District	Tehsil	Number of WSS
1	Mansehra	Mansehra	175
		Oghi	98
		Balakot	238
		F. R. Kala Dhaka	13
2	Battagram	Battagram	41
		Allai	126
3	Abbottabad	Abbottabad	109
	Total		**800**

Sample Collection

Water samples from all the sites were collected in sterile glass bottles from the original source point of all the water systems, brought to the field testing laboratory, processed within 3-6 hours, and stored at −10°C for further analysis where required. A single sample from each of the water system was collected with 10% double sampling and re-analysis to ensure the accuracy of the results.

Participatory Technical Assessment and Sanitary Inspection Survey

A participatory survey at source point by the technical team and the beneficiaries of the respectively water supply systems was conducted following pre-designed questionnaires. The questionnaire assessed the following key indicators at source point;

1. Location of the Source Point;
2. Functional Status of Source;
3. Source Development Measures;
4. Source Protection Measures.

Sanitary Inspection Survey

Sanitary Inspection Survey was conducted to identify the potential risk of contamination to water source. All the potential risks are quantified to evaluate the sanitary risk level. A comprehensive checklist in line with WHO Sanitary Inspection Protocols was used during the sanitary inspection of the water systems (WHO, 2011). The survey analyzed the following parameters;

i. Source development measures

ii. Source protection measures

iii. Potential environmental threats to water quality

iv. Possible measures to reduce the potential threats to water quality

Water Sampling and Analysis

Water sampling from the source points on the basis of WHO recommended standard methods was carried out for all sample water sources. Water quality of the selected schemes was tested to identify the potential risk of contamination and the physiochemical and microbiological status of drinking water.

A sample of water is said to be microbiologically contaminated when it is polluted by Faecal Coliform bacteria. The principal standard indicator for Fecal Coliform is *Escherichia coli* (*E. Coli*). *E. Coli* was tested using the Oxfam-DelAgua Water Testing Kit, which has been developed by scientists at the University of Surrey in collaboration with colleagues at Oxfam (DelAgua, 2018). Besides microbiological parameters the physiochemical parameters of drinking water are also of paramount importance to analyze the quality of source water. The study used the following key parameters to analyze microbiological and physicochemical quality of the source water;

i. Microbiological quality and those parameters that control microbiological quality (disinfectant residuals, pH and turbidity)

ii. Parameters which cause rejection of water[1] through visual inspection (these include turbidity, taste, color and odor of water)

Results

Technical Assessment and Sanitary Inspection

Source Development and Protection

Out of the 800 water supply systems served through 1,359 sources (817 based on surface water and 542 on springs), only 70 (5%) are developed using apt engineering and required minor repairs to switch them into improved sources, while 1,289 (95%) sources serving the water supply systems were either undeveloped or unimproved supplying contaminated drinking water throughout the year to the beneficiary communities due to inappropriate or indecent engineering at source point (Figure 1).

A high majority of sources developed on surface water sources lacked appropriate or well-engineered structures at source points i.e. cut-off wall (9%), slow sand filters (22%), gravel pack with strainer (8%) and lack of filter pack in infiltration galleries (1%). Source served through springs showed similar statistics with 169 (12%) sources lacking a spring box, 137 (10%) without diversion channels, 78 requiring flood protection and retaining walls (4% and 2% respectively). Out the total 107 (8%) systems were served through pumping sources and lacked apt engineering at all sites (Figure 2).

Figure 1: Improved vs Unimproved Sources

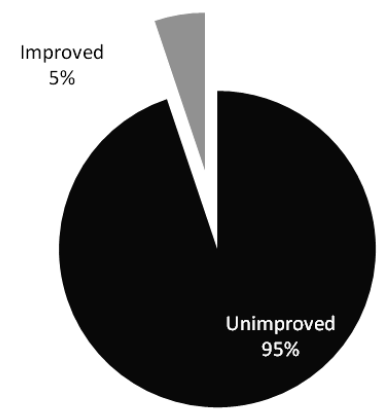
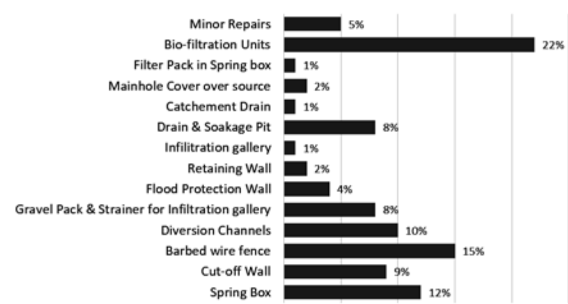


Figure 2: Missing Water Source Development Components in sample systems

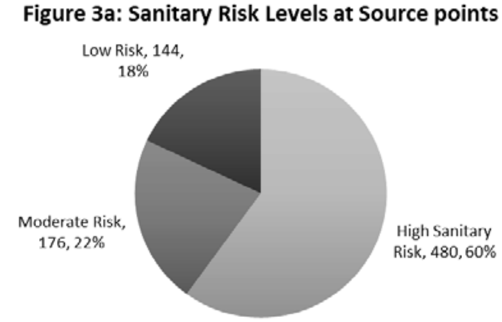


Sanitary (Environmental) Hazards to Source

Sanitary Inspection survey at source point of 800 drinking water supply systems revealed that 60% (478) systems were exposed to high sanitary risk according to WHO standards. While 22% (182) were exposed to intermediate and 18% (140) systems were exposed to low sanitary risk (Figure 3a).

The findings also showed that most of the environmental or sanitary hazards are due to inappropriate engineering at the source point (Figure 3b), i.e. inappropriate site selection, poor or inapt source development, absence of source protection measures etc.

Figure 3a: Sanitary Risk Levels at Source points



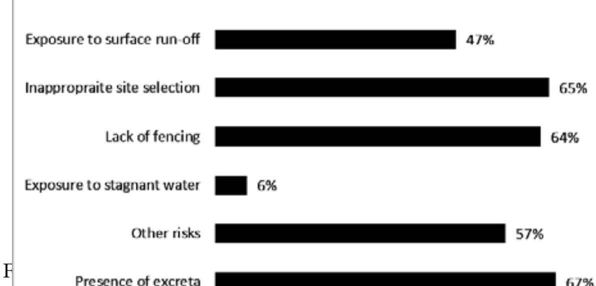
Water Quality

Physiochemical Quality

The study found that out of the total 800 water supply systems 648 (83%) were served with physiochemical safe water according to WHO, NSDWQ and PSQCA/MoE standards (WHO, 2011 and MoE, 2008) right from the source while remaining 152 (17%) systems had physio-chemically contaminated water at source point.

The findings state that out of the total sources tested for physiochemical parameters 15 (2%) had water with objectionable color as well as the turbidity value for the same sources were recorded as higher than permissible limit (<5 NTU) for drinking water. For the remaining parameters tested for physical quality the sources were found safe with their recordings within permissible limits according to WHO, PSQCA and NSDWQ standards.

Figure 3b: Identified risks at source points



[1] WHO. 2007. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the F pearance. https://www.ncbi.nlm.nih.gov/books/NBK442378/.

The study also found that the physical parameters especially turbidity, taste, odor and color were found above permissible limits broadly due to inappropriate structures at source points, i.e. source points lack protection measures like diversion channels and catchment drains against run-off resulting in high turbidity of the drinking water.

Microbiological Quality

Results from microbiological testing exercise using *DelAgua* kit showed that 648 (81%) of the total water supply systems are providing microbiologically unsafe water contaminated with *E. Coli* while water was found safe in 152 (19%) of the total 800 water supply systems.
The study also discovered that water supply systems served through surface water sources and inappropriate engineering structures were mostly contaminated microbiologically compared to the spring and ground water sources.

DISCUSSION

Inadequate or no source protection and development measures for the water sources during the emergency response has negatively affected the statistics for safe drinking water in the sample areas. The findings from the current study found that over 95% of the water supply systems lacked an improved or well developed and protected source. The current state of the water sources is primarily a consequence of inappropriate and inapt engineering practices that ultimately resulted in decay of the sources with a wide majority of damaged sources beyond the point of repair or exposed to all sorts of environmental hazards.
Khyber Pakhtunkhwa (KP) Province of Pakistan is on track to meet its MDG targets on drinking water while a steady growth can be anticipated in achievement of the SDG goals. A latest survey report by UNICEF and KP Government shows that 91.3% of the population in the province has access to an improved source (UNICEF/GoKPK, 2018). This does not mean that the water is necessarily safe from source to the user end. Intermittent supplies in urban areas and insufficient treatment in rural communities mean that the water is often contaminated. Only 38% of all water in the province is estimated to be safe to drink (IRC, 2008). But the statistics from the current study discovered even more distressing results with over 83% of the sample schemes supplying unsafe water. The current statistics would be a major stumbling block to achieve the SDGs for drinking water as well as primary health in the sample area and eventually the entire KP, as the sample schemes of the current study are serving over 70% of the population in the sample areas.

Figure 7: An inadequately engineered and unprotected source point

Out of the total 800 water supply systems 92% are gravity based systems served through springs (65%) or surface water sources (35%). The quality of water in schemes supplied through springs can be improved by developing apt engineering structures like spring boxes and covered catchment chambers etc. but improving the quality of water in systems served through surface water would be a sturdy challenge (Figure 8). In KP 49.6% of the population, depends on water from a dug well, pond, river, canal or stream (GoKP, 2017). To improve the microbiological quality of water at scheme level slow sand filters are the only viable solution for the sample area. But application of slow sand filters at scheme level again could face constraints like cost of maintenance, capacities of communities and line agencies and above all the cost of application. Therefore, application of water quality improvement measures (source protection and development) at source points will only be a short-term solution to the problem, the study in view of the current findings recommends that reliance on surface water should be reduced wherever an alternate spring or ground water source is available in the sample areas. Water quality improvement measures can be proposed for sites where no alternate source of drinking water is available.

Figure 8: A surface water source serving a sample water supply system

Findings from the study state that out of the total 800 water supply systems 17% were served with physio-chemically contaminated water (with high turbidity, pH levels and objectionable color, odor and smell) according to set standards by WHO, PSQCA and NSDWQ (MoE, 2008). The primary reasons found through sanitary inspection were frequent and easy and unwanted human and animal access and poorly designed source structures with inappropriate engineering (Figure 8, 9).
The study also found that the physiochemical parameters especially turbidity, taste, odor and color were found above permissible limits broadly due to inappropriate structures at source points exposing the source water to different contaminants, i.e. source points lack protection measures like diversion channels and catchment drains against run-off resulting in high turbidity of the drinking water (Figure 7, 8, 9).

Figure 9: Undeveloped spring box of a sample water supply system

In summary, the study has reached the outcome that haphazard emergency response could lead to long term sustainability issues for water services. The challenges include but are not limited to supply of contaminated water to the communities leading to health problems, non-functionality of the water systems exerting burden on the state's economy, rising cost of water negatively effecting the social well-being and non-achievement of global, national and regional commitments.

CONCLUSION

Unplanned and uncoordinated transitory emergency response can lead to long term issues relating sustainability of the drinking water supply systems and hence the primary health of the beneficiary population. Keeping in view the findings from the study it is suggested that the emergency response should only focus on life saving activities, while disregarding the long term planning areas of emergency stricken areas. Responding to issues requiring long term planning and comprehensive actions during the emergency response stage and with projects of shorter duration can lead to long term problems for the concerned government line agencies, as the case with most of the sample systems of current study that require even a greater rehabilitation and recovery effort after the unplanned transitory emergency response. Furthermore, awareness pertaining safe water and developing and maintaining safe water systems should be created among line agencies and general public.

RECOMMENDATIONS

i. **Developing "Safe water sources"** - Development of safe water source is one of the key factors towards the sustainability of a water system. There are some key factors which should be considered to make the sources safe from the environmental hazards, i.e. assessment of the environmental hazards or sanitary inspection, appropriate location, pre- and post-development water quality analysis, application of apt engineering and community ownership. The principal and mandate of developing safe water sources at all stages of responding to disasters and emergencies should be adopted and executed by concerned line agencies and service providers in water and sanitation sector.

ii. **Improving Capacities of Line Agencies** - The capacities of the concerned line departments in developing and designing safe sources is a major barrier in achievement of safe water sources. The term *Safe water* is not well defined to the line departments and the focus is on provision of water rather than *safe water*. *Practice and learn* or *learning through experience* is the only source of knowledge and skill improvement with the professionals in the line agencies. Being unclear of the water safety the line departments are not in a position to implement or instruct to implement safe water systems either in standard conditions or emergency response. The solution to the issue is a capacity building unit within line agencies which may with the time upgrade the knowledge and skills of the professionals involved.

iii. **Emergency Response Regulation** – During disasters and emergencies the local setup is shattered in most of the cases and coordination between the stakeholders is one of the challenges that the responding agencies and organizations of both government and non-government backgrounds face. An independent platform at national level to ensure a coordinated and regulated effort during emergencies will reduce the waste of resources, as well as serve as a regulatory authority and will also identify the potential areas requiring a higher recovery effort. Such platform will also ensure implementation of water project according to set standards and developed SOPs and will also regulate and confine the agencies responding to issues requiring long-term planning in projects intended to serve short-term benefits.

iv. **Community Involvement in Rural Areas** – Community involvement throughout the design, implementation and operation of the water systems is a major building block of sustainability. The water and sanitation sector has used different concepts of community participation in the projects implemented in the emergencies, e.g. Contribution of labor and materials, financing of investment and operations and community organizations as in charge of supplying water services. All the approaches above either fully or in parts are implemented or an attempt to implement them has been made through different projects at different times during emergency response but the end result to the problem is null in most of the cases. The main reason behind the failure is top to down approach of such projects resulting limited coverage, delayed return on investment, lower impact to overall interventions, and higher implementation costs.

v. **Uniform SOPs for Emergency Response** - Presence of a number of agencies serving the sector especially during emergency response with different levels of services, technologies, standards and mandates is also a constraining factor leading deprived service delivery. A possible solution to the issue is merging all such service providers into one institution to utilize combination of several alternative technologies available with different service providers through one platform and mutually agreed Standard Operating Procedures (SOP).

vi. **Hidebound Political Interests** – It is also observed that some of the drinking water systems during emergency response are proposed under some political influence with intention to serve the parochial or hidebound political interests. The agencies implementing water projects during emergency response to gain short-term benefits usually compromise on quality of design and focus on completion of the system under such conditions resulting in poorly designed schemes.

To counter the influence of the politicians, local elites and power brokers during the emergency response and rehabilitation, a third part validation system should be in-place.

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