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URBAN ECOSYSTEMS AND HEALTH IN KATHMANDU: COMMUNITY-BASED BIOLOGICAL ASSESSMENT OF DRINKING WATER SOURCES

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Abstract

Rapid urbanization and population growth in Kathmandu impedes the Nepal Drinking Water Supply Corporation to provide an adequate supply of safe water to the city. Supply to households is intermittent during the dry season. In wards 19 and 20, only half of the households have a direct connection. Because of this limited and insecure water availability, a large portion of the population depends on unprotected and hygienically unsafe water sources for domestic and commercial use (including ward hotels, restaurants, butcheries and slaughtering houses). Community residents and the research team on urban ecosystem health considered improving the quality of drinking water essential to sustainable community health. In 2001-02, an inventory and testing of water sources in the wards was carried out with funding from IDRC, Ford Foundation and Winrock International. Policy makers of the city and health authorities were sensitized, simple water testing technologies were transferred to the wards' health clinics, and water quality monitors from the respective wards were trained. Over 150 different water sources were monitored, including traditional community taps (stone taps), household connections, shallow wells, deep wells, and household water storage tanks, using a low-cost bacterial test (H_2S) prepared locally. Ten percent of sample replicates were also tested for Total Coliforms and E.coli as quality control. High bacterial contamination was detected during spring and monsoon periods in most water sources (over 90% of Stone taps and wells). The stone tap water is less contaminated than tubewell water i.e. $P>0.05$. While there is no significance difference between NWSC supplied direct tap water and NWSC supplied stored water i.e. $P<0.05$. The water in the distribution system was slightly better, with 70% of household taps in ward 19 and 30% of taps in ward 20 exceeding national drinking water and WHO standards i.e. E.coli count is <3/100ml of water. A water treatment strategy was initiated, including the promotion of safe storage and handling practices, and chlorination. Several stone taps were rehabilitated with funding from the city government. The program effectiveness and sustainability will be evaluated in the coming project phase.

Introduction

Water provides a habitat for a wide variety of organisms including micro organisms of medical significance. Faecal pollution of water supplies may lead to the introductio n of a variety of intestinal pathogens or enterobacteria that cause water borne diseases (Maharjan, M., et al., 2000). Coliform are a well recognised indicator of bacteria for faecal contamination. Microbiological potability standards for drinking water in most developed countries rely on the detection of total Coliform and *E.coli* (a Coliform itself) as markers for human pathogens. The Coliform test can, therefore, best serve as an indicator of treatment efficiency or the integrity of a distribution system. *E.coli* the most, discriminating marker for faecal contamination, and is therefore the microbiological indicator of choice for drinking water potability and safety. Drinking water safety dictates that no *E.coli* should be present (Kravitz, J.O., et al., 1999).

Intestinal bacterial pathogens are widely distributed throughout the world. Those known to have occurred in contaminated drinking water include strains of *Salmonella*, *Shigella*, enterotoxigenic *E.coli*, *Vibrio cholerae*, *Yersinia enterocolitica* and *Campylobacter fetus*. These organisms may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal dysentry, cholera or typhoid. Potable water used for drinking and bathing, if it contains excessive numbers of organism such as *Pseudomonas*, *Flavobacterium*, *Acinetobacter*, *Klebsiella* and *Serratia*, may produce a variety of infections involving the skin and mucous membranes of the eye, ear, nose and throat (WHO, 1984).

Many factors such as individual, social, economic epidemiological, environmental and so on –complicate the issue (Thompson, J and Cairncross, S., 2001). Globally more than 1000 million people are without ready access to adequate supplies of safe water and water borne diseases is a major cause of illness and premature death, especially among children in developing countries (Tulchinsky, T.H., 2000). Due to the absence of adequate sanitation, reliable water supply and sanitation services, more than 15 million children aged 0 to 4 die each year (UNICEF, 1997) (Dold, C., 2001).

There is a plentiful water supply in Nepal, but the facilities for safe drinking water and for excreta disposal can be woefully inadequate (Nath, U.R., 1983). In Nepal much of poor health of the communities in the country is due to lack of safe and potable drinking water. The incidence of water borne diseases in the country is high. An outbreak of typhoid and amoebic dysentery occurs quite frequently and parasitic infections are common. Sanitation is poor, resulting in the fecal matters entering into the water supply. (ABD, 1985; Shrestha and Kane, 1983, Collins, 1985; New Era 1983; DISVI, 1989) indicates that one third of the deaths of children under 4 years of age in rural areas is due to water borne diseases.

Drinking water is collected from unsafe surface sources outside the home; water may become contaminated after collection, either during transport or storage in the homes. Even municipal piped well water is unsafe because of inadequately maintained pipes, low pressure, intermittent delivery, and lack of chlorination and clandestine connections. Contamination of water may also occur during household storage, which was noted in surveys conducted by WHO in the 1960's. They observed that drinking water taken from the piped supply was stored for cooling in earthen jars that were faecally contaminated. Various studies conducted showed faecal Coliform concentrations were generally and sometimes dramatically, higher in stored water than in source water.

Some common water sources in urban areas are tap water; Nepal Drinking Water Supply Corporation (NWSC) provides the household tap facility, two times per day during rainy season while only once a day for 1-2 hours in other seasons. Comparatively, tap water supplied by NWSC is much safer for drinking than that of natural water sources because they treat water before distribution. Besides the tap water supplied from the NWSC, the community people must have to rely on other natural water sources to meet their daily demand. The important ones are the stone taps, tube wells and wells. Due to insufficient water supply from NWSC, community people extensively use these sources also in their daily life either for drinking or for washing, bathing and for the toilet use.

Safe drinking water

Access to safe drinking water is a basic human need that remains unmet for millions of people worldwide. According to the world Health Organization (WHO), more than 1.4 billion people around the world consume water that is unsafe because of contamination with potentially harmful microorganisms or toxic substances. Each year diseases associated with dirty water are responsible for 2 million deaths. Humans can acquire bacterial, viral and parasitic diseases through direct body contact with contaminated water as well as by drinking water. Diarrhoeal diseases, arising mainly from unhygienic drinking water and unsanitary conditions of the water environment account for nearly 1/3 of all child death. Approximately 30,000 children under five die of diarrhoea each year. Disease arising from the ingestion of pathogens in contaminated water has the greatest impact world wide including Nepal.

The Department of Drinking Water Supply HMG/N and Nepal Water Supply Corporation (NWSC) are responsible for supplying drinking water to the municipal areas of Kathmandu. NWSC collects water from 17 spring sources located in the hills surrounding the Kathmandu valley. According to NWSC, records showed a total of 97,711 connection (20.9%) and 1,275 stand post connections (3%) during July and August 1997 (SILT and DRTC 1997, Tiwari 1999). The existing water supply in NWSC service area is not equitable. Some consumers in low–lying areas and near transmission mains enjoy 24 hours supply, whereas most of the consumers receive only a few hours supply in a day. Consumer surveys reported that only about 34% of the total 78.46 connections have either good or sufficient water flow, (Tiwari 1999) co-relates, since they have limited water supply and sometimes not for weeks. Most of the urban people must depend upon hygienically unsafe, unprotected and untreated, stone tap water, well water and tubewell waters.

Methodology

An existing water sources inventory was prepared by a transect walk. H_2S paper strips were prepared both inside the test tube and bottle as well as for stock paper strips in the laboratory. Test tubes and bottles were sterilized with the media coated paper strips. Coliplate and colistrip specific antigen coated commercial plates (Canadian Products) were used. Water samples were collected from all the identified water sources in the community. H2S test was performed from the entire sample while more than using Colistrip and coliplate as a quality control tested 10% of them. The emphasis has been on the sources which people frequently use in their daily life. The pollution levels were measured on the basis of bacterial indication in the incubated sample up to five days if temperature remain below 30^0c and if temperature was in between 30 – 39^0c the measurement of pollution level was taken within three days. If the sample didn't indicate the presence within the allocated time period, the samples were considered as a negative sample.

The colistrip is a convenient test for a quantitative measure of total coliform and *E. coli* density. The test is designed to test surface water, recreational water, processing water and wastewater. The colistrip contains selective media to provide nutrients to stimulate the group of coliforms and *E. coli*. The media also contains inducers and chromagenic/ fluorogenic substrates. These substances react with specific enzymes indicative of coliforms and *E. coli* to provide color change to blue/green and fluorescence by coliforms and *E. coli* respectively. Colistrips contains only 16 wells, while coliplate contains 96 wells. This test is fast and the most sensitive test for detection of hydrogen sulfide producing bacteria and bacteria, which don't produce hydrogen sulfide gas such as *E. coli*. It is a completely enzyme based test by which results can be obtained within a maximum of 24 hours, but the samples should be incubated at 35 degree c not below than 30 degree c and not more than 39 degree c.

Results

Water Quality Status of Ward 19

Among the various water sources identified in ward 19 within the project period, a total of 78 different water sources had been tested. The result revealed that 47% showed positive results i.e. presence of faecal contamination on the second day while 28% shows positive testing on the first day. Only 8 samples were found to be negative, i.e. free of pollution, among the total samples tested. The indication of positive results within the first and second day indicates high contamination of the water samples with hydrogen sulfide producing bacteria of human and animal origin fecal materials and are not safe to drink unless treated. Most of the ground water and surface water source showed positive results within the first and second day, indicating higher contamination but in comparison to them the NDWSC supplied tap water was less contaminated and were found to be treated during distribution. But the problem is the water from the tap which remains stored in the household for consumption purposes.

Among 78 different water sources tested by H2S method, 38 of them were further incubated by colistrip or coliplate method to detect the coliforms and *E. coli* densities. In ward 19, most of the samples contained <100 bacteria as a whole but most of the tube well water contained coliform densities in between 100 and 500. Only one of the stone tap water was found to contain more than 500 bacteria per 100ml of the water sample, while most of the open wells were found to be heavily polluted. In some of the samples *E. coli* bacteria level was found to be at a risky level.

Table 1: Bacteriological pollution level in different water sources of ward 19.

Sources			**%**	**Coliplate/ colistrip results**

	Total sample tested			Coliform MPN range	*E. coli* MPN range
Tube wells	26	23	29	<16 - 405	<16 - 938
Well (Open/ Closed)	10	9	11	<16 - 1696	<16 - 964
Stone tap	9	9	11	<5 - 469	<5 - 307
NDWSC(Direct)	6	4	5	<5 - 28	<5 - >16
NDWSC(Stored)	27	25	32	<5 - 938	<5 - 938
Total	78	70	90		

There are a large number of ground water as well as surface water sources used by community people. A total of 26 tube wells, 10 open and closed and 9 stone taps, were identified as other water sources used in daily activities. Besides those natural water sources, most of the households in the community have connected the tap water for drinking purposes. Since water supplied from the Nepal Drinking Water Supply Corporation is insufficient, most of the people who have connected taps store the water either in the reserve tank or in another container in the household. All the water sources were tested during this period. The result revealed that 90% of the sources were found to be contaminated with coliform bacteria and *E. coli*. A maximum number of ground water sources and surface water sources i.e. 29% and 11% and 32% of the stored water sources were found to be positive for H_2S test. Similarly minimum to maximum numbers <16 – 964 E.coli and <16 – 1696 coliforms were detected in ground water and surface water sources in Ward 19. Few coliforms and pathogenic *E. coli* bacteria were detected from the direct tap water sources distributed in the ward which are in a tolerable limit. But in the case of stored tap water for drinking purposes, some of them contained large numbers of pathogenic bacteria, which are at an intolerable limit.

Water Quality Status of Ward 20

In Ward 20, among the total 75 different water sources tested, maximum samples showed positive result within second day of culture i.e. 44% and least 3% showed positive result on the fifth day of the incubation. 24% of the total samples tested showed positive result within 24 hours. The result indicated that maximum number of water sample tested contain medium pollution and there are few sources which didn't showed positive results for the hydrogen sulfide test i.e. 16 samples.

Regarding the source-wise pollution in ward 20 a maximum number of ground water and surface water sources of the community are heavily polluted with fecal coliforms. 25% of the total tube wells tested (34) have medium bacterial pollution while 9% of them contain high levels of pollution. In the case of the stone taps of the community each and every stone tap found to be containing maximum pollution compared to other ground water sources. All of the stone taps showed positive result within 24 hours of incubation. It is an important fact that most of the community people in this ward frequently use these water sources for their daily activities including drinking. Although there is tap water in their household they are found to be using this stone tap water for their other household activities. But there are no alternatives for the people who live in tenaments around the stone tap area; those people completely depend upon the tap water sources.

Table 2: Bacteriological pollution level in different water sources of ward 20

Sources	Total sample tested	"+" result for H2S	%	**Coliplate/ colistrip results**	
				Coliform MPN range	*E. coli* MPN range
Tube wells	34	31	41	<5 - >1696	<5 - 240
Well (Open/ Closed)	12	12	16	>938	>938
Stone tap	5	5	7	146 - >1696	<5 - >1696
NDWSC(Direct)	3	1	1	<3 - 102	<3 - <5
NDWSC(Stored)	21	13	17	<3 - 275	<3 - >938
Total	75	62	83		

In ward 20, during this period a total of 75 water sources have been tested for bacteriological pollution covering all the ground water sources such as tube wells and wells and surface water sources such as stone taps. A maximum number of pollution levels were detected in tube well water i.e. 41% and in as a whole 83% of the water sources tested was found to be bacteriologically polluted or not safe for drinking. Water supplied from the Nepal Drinking Water Supply Corporation was found to be comparatively safe for drinking purposes. Total coliform level and *E. coli* densities revealed during the analysis were <5 – 1696 as shown in the above table in natural water sources.

Table 3: Source wise bacteriological pollution level in different water sources of ward 19 & 20.

Sources	Total sample tested	"+" result for H_2S	%	**Coliplate/ colistrip results**	
				Coliform MPN range	*E. coli* MPN range
Tube wells	60	54	90	<5 - >1696	<5 - 938
Well (Open/ Closed)	22	19	86	<16 - 1696	<16 - 964
Stone tap	14	14	100	<5 - >1696	<5 - >1696
NWSC (Direct)	9	5	55	<3 - 102	<3 - >16
NWSC (Stored)	38	38	100	<3 - 938	<3 - >938
Total	153	142	93		

During the project period a total of nine sets of experiments in ward 19 and ten sets of experiments in ward 20 were performed both by using the H_2S test as well as coliplate or colistript method. We have covered a maximum number of ground and surface water sources for the tests. Besides these natural water sources used by the community people frequently in their daily life, other important sources of drinking water supplied by the NWSC, both collecting directly and from the stored, also tested incubating the sample water. A total of 153 water sources were tested, among them 142 showed a positive result for the H_2S test which showed maximum contamination levels in the community water sources. All the stone tap water samples collected from different localities of both of the wards showed positive results for the H_2S test.

While 54 tubewells out of 60 and 19 open wells out of 22 i.e. 86% of total sample studied showed positive result for this test. Regarding coliform and *E. coli* densities level it is shown in the above table 23.

Table 24: Sourcewise total coliform and *E. coli* densities measured by coliplate and colistrip in ward 19 & 20.

Sources	No. of sample tested	*Pollution level detected*					
		Total coliform detected			*Total* E. coli *detected*		
		<100	100-500	>500	<100	100-500	>500
Tube well	30	18	9	3	23	6	1
Open/Closed well	6	3	1	2	2	1	3
Stone tap	9	2	6	1	5	4	-
NWSC(Direct)	5	4	1	-	4	-	-
NWSC(Stored)	16	20	5	1	24	-	2
Total	76	47	22	7	58	11	6

Coliform and *E. coli* densities of the water sources play a very important role in a water quality monitoring system. Among the total 153 water samples tested in both of the wards, 76 of them were incubated in coliplate or in colistrip method. The result showed that a maximum number of the examined samples showed coliform and *E.coli* levels below 100 cells per 100ml of the water. Out of 76 samples incubated, 22 samples showed medium pollution while 11 samples showed *E. coli* levels in between 100 – 500 cells per 100ml of water samples. A total of 7 samples were found to be containing greater than 500 coliforms and 6 samples found to be containing *E.coli* densities greater than 500 cells per 100ml of water.

<u>Water treatment strategy applied in the community:</u>

Water treatment demonstration training was organized separately for the community leaders, ward members, consumers and ward chairman in ward 19 and 20. For this purpose 500 litres hiltake plastic water tank, clorinometer and other supplies were distributed to the ward office. Water experts from NWSC and four monitors demonstrated the method of clorination and testing of clorinated water.

Discussion

In Nepal, water and hygiene related diseases are responsible for 8% of all deaths in the general population. According to the country profile by the Ministry of Health, 1997, infective and parasitic diseases constituted the largest single (31.27%) cause of morbidity in the general population. Diarrhoeal diseases, arising mainly from unhygienic drinking water and unsanitary conditions of the water environment, account for nearly 1/3 of all child death. Disease arising from the ingestion of pathogens in contaminated water have the greatest impact worldwide. In the national context, the under 5 mortality rate was 118.3 per 1000 lives births, among them

1279 deaths (10.29% CFS) under 5 years were only from diarrhoeal diseases (Maharjan, M., et al., 2001).

About one in every thousand *E. coli* bacteria is found in an adult's intestine. In a new borne babies intestine this type of bacteria is more abundant. *E. coli* from part of a group of rod –shaped bacteria known as coliform organisms. They are important in water quality testing because simple means to detect their presence in water have been developed over the years. As it has been mentioned earlier, coliform bacteria are found numerous in our small intestine and easier to detect than pathogenic micro organisms. In other words, if tests show that coliform bacteria are in the water then there is a pretty good possibility that there are also microorganisms in that water that cause disease.

Mara and Feachem (1999) classified water and excreta related communicable diseases into seven categories. Feco-oral water borne and water washed diseases: non feco-oral water-washed (skin and eye) diseases: geohelminthiasis, taeniasis: water-based diseases (bacterial and fungal as well as helminthic); inset vector diseases and rodent-vector related diseases. The global burden of some of those diseases in 1990 is reviewed. Water and excreta related diseases were responsible for 2,700,000 deaths in that year (5.3% of all deaths) and for the loss of all, 93,200,000 disability adjusted life years (6.8% of all DALYS). Almost all these deaths and lots of DALYS occurred in developing countries, 99.9and 99.8% respectively. Water quality management is less prioritized, or not at all, in developing countries including Nepal. Only 30% of world's population have a guaranteed supply of treated water including developed countries, while the rest, 70%, depend on wells, bore holes and uncertain sources of water supply.

During the rainy season the volume of water bodies and blow of surface water sources increases in this season, water bodies become contaminated due to seepage of sewage wastewater and run off from adjacent land. Simultaneously total bacterial and coliform count increases along with the nature of the population. During the dry summer season, water volume decreases and contamination levels increase, which enhances the high bacterial count. This situation is reflected in explosive outbreaks of enteric diseases ad epidemics occuring more during the dry summer season and rainy season than in the winter season (IUCN1992).

All the natural water sources, such as ground water sources, like tube wells and deep wells of wards including surface water sources like stone taps, are neither treated nor protected properly. In some locations some of the personal tube wells remain protected, closed from outside but the waster water drainage pipe is not so far from the wells and tube wells. Physical characteristics of most of the tube well water are not so clear and are found contaminated with the soil and sand particles, and transparency is also not very clear. There are a few tube wells found in some locations of both wards which look clear and have no odour but are bacteriologically not safe. Only the tap water supplied from Nepal Drinking Water Supply Corporation is treated. The problem is in the distribution system where most of the drinking water pipelines are brought parallel to that of the waste water drainage pipelines. Hence during the rainy season most of the drainage pipelines have broken down and contaminate the drinking water. The principal reason of the drinking water contamination are due to the use of unrepaired old pipeline systems for distribution, parallel arrangement of the drinking water pipeline with that of the drainage system and irregular supply of the drinking water in the pipeline. When drinking water is not supplied in the pipeline they remain filled up with the air. If there is waste water around them very easily the waste water are sucked in to the drinking water pipeline and at the time of drinking water supply the water becomes contaminated, although they are previously treated. So most of the community people complain about fecal matter seen in the drinking water at times. All of the information regarding the water sources and water supply system indicate that the possibility of drinking water getting microbiological or fecal contamination is high.

During the bacteriological study of those water samples, test results have revealed that 93% of total samples tested by H2S methods showed positive result, of which a maximum number of tube wells, 54 out of 60, tested in both wards showed they were microbiologically not safe for drinking purpose. While cent percent of the stone taps showed positive result, similarly 19 deep wells out of 22 showed the same type of result. This result indicates that most of the ground water sources and surface water sources of the community are not safe for drinking. Hence the people who are using such water are at high risk. Regarding the total coliform and *E. coli* densities in the water sources, a maximum number of the sources detected bacterial densities in between 100 –500 cells per 100 ml of the water sample tested, and below 100 cells per 100 ml sample tested. Although the tap water was found to be less polluted, they were not free from contamination and drinking water remained always a problem because it was supplied sometimes only once a day, or sometimes in two days or sometimes weeks. Hence mostly the community people must rely on local sources such as stone taps, wells and tube wells .

DISVI (1990) carried out microbiological tests of drinking water in seven rural areas of Illam and found that water samples from springs, aquifers and rivers had unacceptable levels of faecal coliform bacteria's ranging from 2 to 2400 cells/100ml. In other studies ENPHO/DISVI (1990) investigated the bacteriological quality of reports from 21 localities, which were found to be faecally contaminated, similar results were obtained. In another study carried out in Baluwa and Gokarna VDC, out of 16 water samples analyzed enteric, pathogenic bacteria *Escherichia coli* was detected from all with total coliform counts ranging from 150 to 1100 cells/100ml. Among them 30% of the samples contained on average coliform counts of more than 100cells/100ml. In our study similar types of result was obtained.

The Department of Drinking water supply HMG/N and Nepal Water Supply Corporation are responsible for supplying drinking water and sewerage service to the municipal areas of Kathmandu. NDWSC collects water from 17 spring sources located in the hills surrounding the Kathmandu valley. According to their records a total of 97,711 connections with 76,050 metered connections (77.8%), and 20,386 non metered connection (20.9%) and 1,275 stand post connection (3%) during July August 997(SILI and DRTC 1997,Tiwari 1999). The existing water supply service is not equitable. Some consumers in low-lying areas and near transmission mains enjoy 24 hours supply, whereas most of the consumers receive only a few hour supplies in a day. Consumer surveys reported that only about 34% of the total 78.46 connections have either good or sufficient water flow (Tiwari 1999). This statistics and our survey in ward 19 and 20 during 1999 (Joshi et.al.1999) corelates since they receive a limited water supply and sometimes are not supplied for weeks, most of the urban people must depend upon water and tube well water.

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