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Original Article

Revelations of an overt water contamination

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ABSTRACT

Background: Contaminated water sources are major cause of water borne diseases of public health importance. Usually, contamination is suspected after an increase in patient load. **Methods:** Two health teams investigated the episode. First team conducted sanitary survey, and second team undertook water safety and morbidity survey. On-site testing was carried out from source till consumer end.

Investigation was also undertaken to identify factors which masked the situation. Prevention and control measures included super chlorination, provision of alternate drinking water sources, awareness campaign, layout of new water pipeline bypassing place of contamination, repair of sewers, flushing and cleaning of water pipelines, and repeated water sampling and testing.

Results: Multiple sources of drinking water supply were detected. Water samples from consumer end showed 18 coliforms per 100 ml. Sewer cross connection with active leakage in water pipeline was found and this was confirmed by earth excavation. Water safety and morbidity survey found majority of households receiving contaminated water supply. This survey found no significant difference among households receiving contaminated water supply and those receiving clean water. Average proportion of household members with episode of loose motions, pain abdomen, vomiting, fever, and eye conditions was significantly more among households receiving contaminated water.

Conclusion: The present study documents detailed methodology of investigation and control measures to be instituted on receipt of contaminated water samples. Effective surveillance mechanisms for drinking water supplies such as routine testing of water samples can identify water contamination at an early stage and prevent an impending outbreak.

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Introduction

Health of a population can be determined by evaluating the quality of drinking water supply.¹ Contaminated water

sources are major cause of transmission of diseases of public health importance. Globally, at least one-fifth of population is using drinking water sources which are implicated to be contaminated with feces. Diarrhea, due to consumption of contaminated water results in more than 5 lakh deaths

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annually worldwide.² In developing regions, the situation is much worse and contaminated water supplies are one of the major sources contributing to high morbidity and mortality.³

All efforts should be made to avoid deficiencies in water supply distribution systems. Drinking-water supply surveillance is “the continuous and vigilant public health assessment and review of the safety and acceptability of drinking-water supplies”.⁴ Early identification of contaminated water supplies and prompt institution of control measures are of utmost importance in water systems security for maintenance of public health.^{5,6} Foundation for prevention and control of waterborne illnesses is laid through assurance of safe and wholesome drinking water supplies.¹ Inadequate treatment facilities, malfunctioning disinfection systems, and inappropriate treatment practices have been found to be related to occurrence of outbreaks.⁷ Besides this, the water transmission system till consumers is also equally important. All the gains of earlier handling of water have potential to nullify if contamination occurs enroute.⁸

Identification of contaminated water supplies can be missed when contamination is intermittent and physical characteristics are unaffected.⁹ In fact, usually water contamination is suspected after an increase in patient load due to water borne diseases reporting to a health set up.⁵ The present study was carried out to investigate and control an overt water contamination but as the investigation proceeded, it revealed a covert increase in disease burden due to water related diseases and factors which had masked the situation.

Background situation

In the setting of a tertiary care teaching institution having multiple residential complexes for teaching faculty, paramedical staff, postgraduates, undergraduates, and paramedical trainees are located inside the campus. Additionally, canteens, cafeterias, mechanical laundry, religious temples, and cook houses are co-located in the campus. Newer expansion, like in most old institutions, has been done in available vacant spaces. As a result, underground water, electricity, and sewage systems are either burdened with additional load or a new system is put in place with little concern for the older one. Further because of the transferable nature of the job, the staff working in water works department is unaware of the layout of pipelines. Multiple health care establishments (HCE) in the form of Medical Inspection Rooms and hospital are present in close vicinity to these complexes. With this background, a water sample from one of the households was received in the department for examination which was foul smelling, turbid, brown colored, and contained larval forms and maggots.

Material and methods

Formulation of health teams

On receipt of water sample, individual carrying the sample was interviewed about the details of water sample. Two health teams were constituted to investigate the situation and concurrently institute control measures. The teams

consisted of faculty, post-graduate trainees, and health assistants undergoing paramedical training. Team members had been trained earlier (as a part of routine teachings) on all aspects related to 'Water'. However, the teams were briefed about the situation and emphasis was placed on conduct of sanitary surveys, water sampling and testing, and conduct of household surveys. Water sampling and testing kits and household survey questionnaires were provided to the health team members at the end of the session. First team carried out sanitary survey of water pipelines to affected residences and second team undertook water safety and morbidity survey.

Pipeline sanitary survey

Multiple site visits were undertaken by the health team to assess the extent of contaminated water supply and identify likely source of contamination. During the survey, at consumer end, starting from the affected household the members of the team tested water quality fanning out in a centrifugal manner till they either reached a house with clean water supply or they located the defect in the pipeline. On-site water sampling and testing was carried out from source till consumer end. They also tested water at the inlet and outlet from overhead water tanks on top of each multistoried building. At the source end, water samples were tested at inlets to pump house, in stored sump water and at outlet of pump house. Onsite testing of water samples included physical examination of the quality of water supplies and testing for presence of free residual chlorine level using Orthotolidine test. Water samples were also collected in sterile bottles using aseptic precautions and sent to Department of Microbiology for Presumptive Coliform Counts.

Manual tracing and earth excavation of water and sewer pipelines were carried out for identification and visual confirmation of contamination sources and to update 'layout' maps. Route along the pipelines was looked for presence of features suggestive of leakages, deliberate break in the lines, water lines crossing the drains, and sewer line cross connections.

Water safety and morbidity survey

Water safety and morbidity survey was conducted among households in paramedical residential complexes to determine any increase in incidence of water borne illnesses and if so, to identify factors which masked the situation. Data were obtained from female heads of households after receiving informed consent. Pre-structured, interview based questionnaires were administered. Data collection was carried out to determine socio-demographic factors, water treatment practices, water storage practices, handwashing practices, occurrence of water related diseases, and treatment seeking behavior during the episode of illness. These factors were compared among those households receiving clean water supply and those who were not to rule out effect of factors other than contaminated water supply which might have led to significant differences in morbidity profile among the groups. Data were entered into excel and were analyzed using SPSS version 21.0.

Results

Baseline interview findings

Interview of the person who brought water sample to department revealed that the sample was collected from one of the household taps in paramedical residential complex on the basis of complaints regarding poor quality of water supply. The water sample was collected during early morning hours during active water supply, for inspection by institute's administrative authorities. The water sample was then sent to department for detailed examination.

Sanitary survey findings

The layout of pipelines (as found out by manual tracing and earth excavation) in the residential complexes is as given in Fig. 1. Paramedical residential complex consisted of 13 blocks (buildings) having a total of 92 households. The layout suggested multiple sources of drinking water supplies in paramedical residential complex. Pre-treated water from the municipal corporation was received centrally in institutional pump house and stored in underground sumps. The stored sump water was pumped twice daily through multiple outlet pipelines from the pump house. Pump house lacked any mechanism for checking of free residual chlorine levels or re-treatment of the stored water before pumping to residential areas. Onsite water sampling and testing showed absence of free chlorine in 10 blocks, in overhead water storage tanks, and at outlet as well as inlet of overhead reservoir. Physically water appeared to have similar characteristics to the sample brought to the department. Contrasting to this, water was found to be of potable nature in remaining 3 blocks of residential complex, nearby teaching faculty residential complex, temple, cook houses, mechanical laundry, and at pump house (source end). Presumptive coliform counts of water samples from consumer end showed presence of 18 coliforms per 100 ml. Community taps, also, located in the vicinity were also found to be receiving clean water supply with free chlorine level of 0.5 ppm.

They were traced to direct tapping's from the municipal water pipeline like 3 blocks of the paramedical residential complex receiving clean and chlorinated water. All the water pipelines till residential houses were in close proximity to sewers with multiple crossovers with water pipeline.

Sewer cross connection with active leakage in water pipeline was found near outlet from the pump house this was confirmed visually by earth excavation as shown in Fig. 2. The location of cross connection and contamination was found to be underground, below an old repaired cemented floor. The water pipeline had a tortuous route at the site and water used to gush out during supply hours through the cracks in the flooring. The area was damp and a leaking, foul smelling sewage chamber was located nearby. Further investigation revealed that the sewage chamber was broken, partially blocked with sewage spilling out in the nearby area. Sewer was laid above the water pipeline without any horizontal or vertical separation and there were crossovers between water pipelines and sewers.

Findings of water safety practices and morbidity profile

Among a total of 92 households, 69 households participated in the study giving a response rate of 75%. Majority of households (54 out of 69 households) were receiving contaminated water supply. As shown in Table 1, on comparison of level of education of female head of household and water safety practices, which are important determinants for occurrence of water related diseases, no significant difference was found among households receiving contaminated water supply and those receiving clean water. Female heads of majority (47.8%) of households had education higher than secondary. Filtration and boiling of drinking water before use was being done in 79.7% and 63.8% households and were similar in both the groups ($p = 0.449$ and 0.731 respectively). Closed container was used for storage of drinking water in 75.4% households. Female heads of majority of households practiced handwashing before cooking, before eating food, after toilet use, and used soap while handwashing (84.1%, 88.4%, 69.6%, and 88.4% respectively). It was also found that households were using alternate sources of drinking water by using community taps

Fig. 1 – Spot map of paramedical residential complex.

Fig. 2 – Sanitary survey finding (schematic diagram): location of source of contamination.

in the vicinity and refilling drinking water bottles from departments/work place. Use of community taps as source of drinking water was significantly more among households receiving contaminated water supply ($p = 0.005$).

Proportion of household members who had at least one episode of water related disease in past 6 months was calculated for each household. As shown in Table 2, average proportion of household members with episode of loose motions, pain abdomen, vomiting, fever, and eye conditions was significantly more among household members receiving contaminated water supply as compared to those receiving clean water ($p = 0.002, 0.033, 0.040, 0.012$, and 0.040 respectively).

Treatment seeking behavior of the household members revealed that majority being paramedical staff, resorted to self-medication and from multiple health care facilities, thus cases got frittered away and no clustering could be ascertained (Fig. 3).

Prevention and control measures

Prevention and control measures were instituted immediately on detection of contaminated water supplies. Staff at pump house was advised super-chlorination of water before pumping into distribution pipelines. Alternate sources of drinking water in form of chlorinated water bowsers were also made

Table 1 – Water safety practices.

Study variable	Households receiving contaminated water supply (n, %)	Households receiving clean water (n, %)	All households (n, %)	p value
Total households	54	15	69	–
<i>Distribution of education of female head</i>				
Primary	12 (22.2)	2 (13.3)	14 (20.3)	0.877
Secondary	16 (29.6)	6 (40.0)	22 (31.9)	
Higher than secondary	26 (48.1)	7 (46.7)	33 (47.8)	
<i>Drinking water treatment practices at home (multiple options)</i>				
Filtration	42 (77.8)	13 (86.7)	55 (79.7)	0.449
Boiling	35 (64.8)	9 (60.0)	44 (63.8)	0.731
<i>Drinking water storage practices</i>				
Drinking water stored	44 (81.5)	13 (86.7)	57 (82.6)	0.639
Closed container used	41 (75.9)	11 (73.3)	52 (75.4)	0.837
<i>Handwashing practices (multiple options)</i>				
Before cooking	47 (87.0)	11 (73.3)	58 (84.1)	0.200
Before eating food	49 (90.7)	12 (80.0)	61 (88.4)	0.250
After toilet use	38 (70.4)	10 (66.7)	48 (69.6)	0.783
Use soap (always/almost always)	47 (87.0)	14 (93.3)	61 (88.4)	0.500
<i>Alternate sources of drinking water (multiple options)</i>				
Community tap	36 (66.7)	4 (26.7)	40 (58.0)	0.005
Refilling from department	21 (38.9)	6 (40)	27 (39.1)	0.938
Purchased water	3 (5.6)	0 (0)	3 (4.3)	–

Table 2 – Morbidity profile.

Study variable	Households receiving contaminated water supply	Households receiving clean water	All households	p value
<i>Average proportion of household members with episode of water related diseases</i>				
Loose motions	0.16	0.02	0.13	0.002
Pain abdomen	0.08	0.02	0.07	0.033
Vomiting	0.03	0.00	0.02	0.040
Fever	0.06	0.00	0.05	0.012
Eye diseases	0.05	0.00	0.04	0.040

available to the households. An awareness drive on home-based water treatment options, safe drinking and storage practices was carried out. Presence of free residual chlorine levels at the source and consumer end was monitored on daily basis and residual free chlorine of at least 2 ppm at the source (pump house) and 1 ppm at the consumer end was maintained. The identified source of contamination was corrected in coordination with engineering department. New water pipelines were laid bypassing the place of contamination. Once new pipelines were laid, flushing and cleaning of entire water distribution system was carried out. The new pipeline laid was kept uncovered till multiple testing for presumptive coliform counts from the source, along the distribution system and at the consumer end was found satisfactory. The sewers were also repaired side by side.

Discussion

The present study documents detailed methodology of investigation and control measures to be instituted on receipt of contaminated water samples. Water contamination is a routine problem faced by public health specialists in the field. However, still it took around 6 months to get rectified. It had to wait for a thorough investigation by a teaching establishment to unearth the cause and identify the cross connection. A common occurrence but uncommon action. The present article reflects a need to reinforce the issues and quick remedial measures highlighting the urgency of issue. During the investigation, unusual increase in disease burden due to

water contamination was also revealed among households receiving contaminated water supply. This was not picked up by the routine daily health intelligence gathering as the affected population had background of medical education and a large proportion undertook self-medication. Also, large proportion of households undertook water treatment and safety practices as well as shifted to alternate sources of drinking water. Thus, the traditional hallmarks of an outbreak were extremely limited and masked. Effective surveillance mechanisms for drinking water supplies such as routine testing of water samples can identify water contamination at an early stage and prevent an impending outbreak.⁵ Absence of free residual chlorine should be considered as an evidence for contamination and prompt control measures should be instituted.¹⁰

Sanitary survey and onsite water sampling and testing enabled the investigators to determine the source and place of contamination. Absence of free residual chlorine at the inlet to overhead reservoir and presence of chlorine at the outlet from pump house provided circumstantial evidence of likely place of contamination. Further, presence of free residual chlorine levels in the sump, at the consumer end of other outlet and in direct tapping's suggested local contamination in the specified outlet pipeline only. Assessment of free chlorine levels along the distribution system and identification of abrupt decrease in free chlorine levels is an effective method to determine likely place of contamination.¹¹

Lack of maps and blueprints disables effective monitoring of water distribution system as well as causes delay in identification of the contamination source.¹² Public health

Fig. 3 – Treatment seeking behavior: frittering of cases.

functionaries should advocate availability of layout maps for their area of responsibility during initial phase of practice. Also, in a phased manner, newer water and sewer pipelines should be laid in places with underground installations of ancient vintage.

Probably because of constraints of space and the circumstances, the principles of Public Health Engineering during layout of water and sewer pipelines got compromised. This was an important factor leading to contaminated water supplies in the present situation. An effective collaboration within the engineers and public health authorities is required to ensure layout of pipelines adhering to the norms of vertical separation of at least 0.5 m and horizontal separation of at least 3 m between the water and sewer pipelines.⁶

Conclusion and recommendations

Public health issues will appear routine and mundane but they continue to occur and need to be highlighted to everyone concerned. Intermittent water contaminations unable to affect the physical characteristics of water supplies can be missed when water quality surveillance is solely based on hospitalization data. A systematic approach on receipt of contaminated water samples is recommended for early identification of the likely contamination source.

Conflicts of interest

The authors have none to declare.

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