Industrial Pollution: *Contamination of Surface Water & Human Health in Veerapura, Bangalore*

Mounica Vallurupalli, Jane Xiao

Alumni, Class of 2009; mounicav@umich.edu, xiaojane@umich.edu

past for drinking or bathing complained of muscle weakness, diarrhea, fever, and skin irritations. They also observed that water formed a cloudy film after boiling and corroded the metal containers used to store the water, supporting the quantitative results demonstrating the hardness of the water. Data from this study will aid the Veerapura community and the Society for Voluntary Action, Revitalization, and Justice (SVARAJ) in their efforts to improve the quality of Lake Veerapura and surrounding water resources available to Veerapura residents.

ABSTRACT

Water quality of Lake Veerapura near Bangalore, India has deteriorated due to uncontrolled dumping of industrial waste. Lake Veerapura receives water from rainfall and industrial effluent streams and may be connected by underground aquifers to bore wells in Veerapura village. Researchers analyzed the extent of water pollution and possible health effects based on chemical analysis of water samples and interviews with 19 families living in Veerapura. Samples were collected from industrial effluent streams, Veerapura lake, and surrounding bore wells. Two sample sets were collected over one month and analyzed at the Karnataka State Pollution Control Board (KSPCB) laboratory for potability and heavy metals. Quantitative results showed that 1) industrial effluent streams violated KSPCB industrial waste standards 2) lake water contained contaminants common to effluent streams 3) bore well water exceeded ISO drinking water standards for hardness. The interviews demonstrated that most families purchased drinking water from the public water supply because they considered bore well water unpotable. The families who had used bore well water in the

INTRODUCTION

Over the past two decades, India's economy has grown dramatically and has sustained an accelerated growth rate averaging at 7% since 1997. Yet, despite this rapid economic growth and industrialization, India still faces many infrastructural and social problems and 25 % of the population lives below the poverty line[1].

With increasing urbanization and industrialization, Indians are facing even more problems in the form of increased exposure to environmental hazards. Some recently established environmental risks in India include microbial contamination of water, air pollution, arsenic and exposure to toxic metals, pesticides or other industrial wastes. While these exposures are severe and are estimated to account for up to 2/3 of the economic costs associated with environmental health damage in metropolitan cities, there is little research to characterize environmental risk factors and drive prioritized policy changes to improve public health[2].

---

1 CIA-World Fact Book, 2009, 12 Feb. 2010.
2 Hu H, Balakrishnan K. The environment and health: an emerging area of research in India. Indian J Med Res. 2005;121: pp711-715.

This study is a preliminary evaluation of an area of industrial pollution in the Doddaballapur Industrial Area near Bangalore, India. The Doddaballapur Industrial Area consists of three groups of industries including the Karnataka State Small Industries Development Corporation (KSSIDC) and two sets of larger industries in the Karnataka Industrial Area Development Board area and an Apparel Park consisting of textile dyeing, washing and printing as well as finishing. Nearby and downstream of these industries is Veerapura village.

Villagers in Veerapura rely mainly on bore wells ranging in depth from 80 to 200 ft to provide water for their livestock, food preparation, and household use. However, the recent growth and expansion of industries in the area has led to increased disposal of untreated effluents and sewage into streams feeding Lake Veerapura. The lake is a shallow lake which at its deepest, after the monsoon season, is 2.5 meters. It is sustained by rain water and deposits from sewage. It is possible that the pollution of Lake Veerapura can pollute soil and adulterate underground aquifers feeding into the bore wells used by villagers. Recent studies by the Department of Mines and Geology have demonstrated that the aquifer system near Go Go Exports, nearby Veerapura, had been contaminated over a radius of 1.8 kilometers.

The aim of this study was to assess the composition of the industrial effluents, the quality of the water in Lake Veerapura and determine whether the bore well water adheres to International Organization for Standardization (ISO) standards for drinking water. Sixteen samples including industrial effluents, lake water, lake sediment and bore well water samples were analyzed. Additionally, we interviewed Veerapura residents about their opinions concerning water availability, safety and their health.

METHODS

Samples

Two sets of samples were taken. Each set contained 4 lake water samples, 4 lake sediment samples, 3 industrial effluent samples, and 5 bore well samples (refer to Figure 1 and 2). Four 1L

water samples and four 500g adjacent soil samples were obtained from the perimeter of the lake. Lake water samples were obtained roughly 1 meter away from shore from the surface of the lake. It should be noted that a larger central water body was present at the time of sampling than is represented in the Google image in Figure 1 due to an outdated satellite image and increased monsoon rains. We were unable to obtain a water sample from the center of the lake, however, it is recommended that one such sample should be collected. Each soil sample was obtained on the lake shore border at 2 to 3 inches depth immediately adjacent to each lake sample. Three 1L effluent samples were taken from the industrial area at a drainage juncture near TATA industry and CIPSA-RIC. Two of the effluent samples contained contaminants from different parts of the large industrial area and one may have contained contaminants from the small industrial area across the street. One effluent sample was obtained from a downstream combined-flow location.
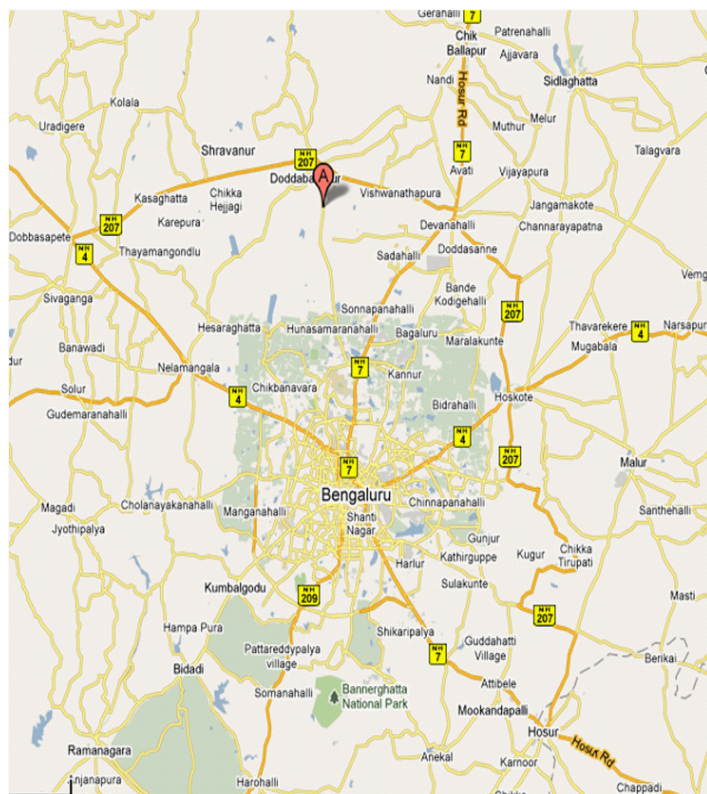
Source: Google Maps
Figure 1: Locations of Doddaballapur Industrial Estate with respect to Bangalore (labeled Bengaluru in map).

Source: Google Earth
Figure 2: Locations of samples. Only 1 marker is shown for the 3 effluent samples, which were taken at a drainage juncture near TATA industry and CIPSA-RIC.

Handling and Processing of Samples

Samples were collected in the morning on May 20th, 2008 and May 27th, 2008 and delivered to the CPCB laboratory within 3 hours from the time of collection. Lake samples were stored in 2L polystyrene containers. Soil samples were stored in 1 quart plastic bags. Biological samples were stored in sterilized glass bottles provided by the CPCB lab and Dissolved Oxygen samples were collected in 300 mL glass containers and treated with Sodium Azide and Manganous Sulfate immediately.

Interviews

Interviews were conducted with families residing in Veerapura Village with the aid of two translators, converting either from Kannada to Telugu and Telugu to English or Kannada to English. Nineteen representatives from different families were interviewed. Families were interviewed from three groups, those living adjacent to the lake, south (upstream) or north (downstream). A convenience sampling of all families that were available and consented to participate was performed.

Survey Design and Rationale

The interview questionnaire first characterized interviewee or household representative by age, gender, and household size. The purpose of these questions was to allow for personal introductions, to make interviewees more comfortable with researchers and to encourage more thoughtful answers to the later questions. The questionnaire then asked if the drinking water supply was obtained from a private bore well or a public water supply. The purpose of this question was to look for any common water supply sources between the interviewed families. Then interviewees were asked to qualitatively describe their drinking water in terms of taste, color, and presence of particulate matter before and after boiling or filtering. The purpose of these questions was to obtain a qualitative description of the drinking water that might indicate the presence or unusual levels of certain types of compounds or a high level or hardness. Finally, interviewees were asked if and why they were or were not satisfied with the quality of their drinking water. The interview questionnaire was designed with the guidance of Raja Rajeshwari, SVARAJ Research Officer.
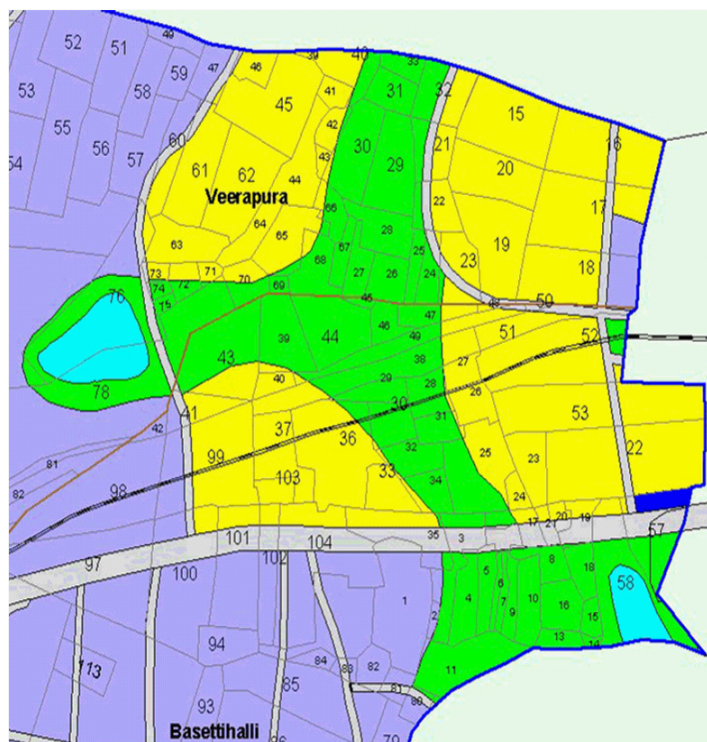
Source: Bangalore Intl. Airport Area Planning Authority
Figure 3: Approximate sampling locations for bore well samples. The Panchayati bore well is located beyond the border of the map, past bore well sample 4.

Water Sample Analysis

The two sets of water samples were analyzed at the Karnataka State Central Pollution Control Board (CPCB) laboratory under the guidance of Mr. Raghavendra Instrumentation used for these experiments was donated by the World Bank. All analyzed water samples were graded based on the Primary Water Quality Criteria for Various Uses established by the CPCB in Table A, except the parameters for which no tests or reagents were available at the lab to perform the experiments Effluent samples were compared against the General Standards for Discharge of Environmental Pollutants in Table B. Lake water and bore well samples were compared against ISO Drinking Water Standards. A sample was considered to "fail" if at least one of the parameters was violated. However when different levels of water quality had the same requirements for a single parameter, the highest possible grade for that parameter was given. Not all parameters from Table A and Table B were tested due to timing constraints of the project. All parameters from the ISO Drinking Water Standards were tested in lake water and bore well samples because the primary concern of the project was to aid SVARAJ's endeavors to improve the quality of drinking water for the Veerapura villagers.

Outline of Methods

Thorough descriptions of all procedures and instrumentation used are available from the Karnataka CPCB.

pH

All water samples were analyzed using the digital Mettler Toledo MP120 pH meter. Meter was calibrated first with a solution of pH 7.0 and then with a solution of 4.0.

Conductivity

All water samples were analyzed using the digital Mettler Toledo MP120 Conductivity meter. Meter was calibrated with a 0.1N KCl solution with an expected conductivity of 2.38 mS.

Turbidity

All water samples were analyzed using Nephelo turbidity meter. The instrument was calibrated with distilled water at 0 NTU and refrigerated concentrated acetate solution at 40 NTU.

Chemical Oxygen Demand (COD)

All water samples were analyzed for chemical oxygen demand. 5 mL 0.25N KCr_2O_7 and 15 mL concentrated sulfuric acid were mixed in COD sample tubes and control tube. Mercury (II) sulfate was added to each tube to remove chloride interference. The catalyst silver sulfate was added to each tube. 10 mL of water sample was added to corresponding COD tube and 10 mL distilled water was added to control tube. If a color change from yellow to green occurred while adding sample, sample addition was stopped, the amount of sample added was recorded and distilled water was added up until 10mL was reached. The samples were shaken vigorously to dissolve any yellow precipitate and then heated for digestion. After 2 hour digestions, 40 mL distilled water was added to each tube and allowed to cool to room temperature. Finally, samples were titrated against 0.05N ferrous ammonium sulfate (FAS) using 3 drops of Rantem Ferrion as indicator. The end point was noted when solution turned from blue to brown. A Metrohm 665 Dosimat dosimeter was used to perform the titration. COD was then calculated according to the formula:

$$COD \left[\frac{mg}{L}\right] = \frac{(Control\ titration\ volume - Sample\ titration\ volume) \times 10,000}{Control\ titration\ volume\ \times Sample\ titration\ volume}$$

Where,

$$10,000 = 5mL\ KCr_2O_7 \times 0.25N\ KCr_2O_7 \times 8\ valency \times 1000L$$

Total Hardness

All water samples were analyzed for total hardness. The samples were prepared by aliquoting 10 mL of each sample into a conical flask with 2 mL of ammonia buffer solution and three drops of Erichrome Black T indicator. The mixture was titrated against 0.02N EDTA until a pink to blue color change was observed. Total hardness was calculated according to the formula:

$$Atomic\ Calcium \left[\frac{mg}{L}\right] = \left(\frac{Titration\ volume\ \times 1000}{Sample\ volume}\right) \times 0.4$$

Atomic Chloride

Bore well samples were analyzed for atomic chloride (Cl-). 25 mL of sample was titrated manually against 0.0282N AgNO$_3$ with 2 drops of K$_2$CrO$_4$ indicator until color changed from yellow to brick red. Atomic chloride was calculated according to the formula:

$$Atomic\ Chloride\ \left[\tfrac{mg}{L}\right] = \left(\frac{Titration\ volume\ \times\ 1000}{Sample\ volume}\right)$$

Alkalinity

Bore well samples were analyzed for alkalinity. 25 mL of sample was mixed with 2 drops of methyl orange solution indicator. Mixture was titrated with dosimeter against 0.02 sulfuric acid until yellow color changed to orange. Alkalinity was calculated according to the formula:

$$Alkalinity\ \left[\tfrac{mg}{L}\right] = \left(\frac{Titration\ volume\ \times\ 1000}{Sample\ volume}\right)$$

Dissolved Solids

Bore well samples were analyzed for dissolved solids. The initial mass of glass crucibles were recorded with a digital weighing machine. 50mL of sample was poured into glass crucible and placed in a hot water bath for 2 hours and then transferred to hot air oven for another 1.5 to 2 hours until all water had evaporated. The crucibles and dried residue were cooled to room temperature in a dessicator and then weighed again. Mass of residue was measured and level of dissolved solids was calculated according to the formula:

$$D.S.[\tfrac{mg}{L}] = \left(Mass_{final} - Mass_{initial}\right) \times 1,000,000$$

It was expected that dissolved solid content would be about 65%-70% of the conductivity reading and this estimation was used in deriving the dissolved solids content for the first set of samples.

Sodium Absorption Ratio

All water samples were analyzed for sodium absorption ratio. The flame photometer was calibrated with known solutions of 0, 20, 40, 60, 80, and 100 ppm sodium and samples were either directly read or diluted before being used for analysis.

Heavy Metal Analysis

All water samples were analyzed for presence of the following heavy metals using the GBC Avanta (Version 1.32) Atomic Absorption Spectrometer: copper, lead, zinc, nickel, total chromium, hexavalent chromium, cadmium, iron, and manganese. In the case of hexavalent chromium, if no total chromium was detected within the sample, analysis for hexavalent chromium was not performed. The analysis for water samples was performed by CPCB staff.

Ammonical Nitrogen

50 mL of each sample was placed into a small beaker. The sample was distilled and collected in a second beaker containing 10 mL of boric acid. A 25 mL sample of the distillate was titrated with 0.02N H$_2$SO$_4$ and addition of mixed indicator allowed for the visualization of the endpoint which was a color change from green to purple. Free Ammonia is a proportion of ammonical nitrogen that is dependent on the pH. The preliminary test for ammonical nitrogen involves adding two drops of Nessler's reagent to 50 mL of sample and observing whether the solution turns yellow.

Phenolic Compounds

50 mL of each sample was added to a Nesslers tube with 2 mL of ammonia buffer and 3 mL each of aminoantipyrine and potassium ferricyanide. After careful mixing, the presence of a pink color indicates the presence of phenol. In the absence of a color change, phenolphthalein was added to check if the reagents were working properly.

Cyanide

Two solutions were prepared:

1. Chloramin-T-solution: 1 g white chloramin-T powder was dissolved in 100 mL DI water. Prepare weekly and refrigerate between uses.

2. Pyridine Barbituric acid reagent: 15 g barbituric acid dissolved in 250 mL DI water. Add just enough water to wet sides of flask and wet the acid powder. Add 75 mL pyridine and mix. Add 15mL concentrated HCl, mix, and cool to room temperature. Dilute to 250 mL volume and mix until barbituric acid is completely dissolved. The solution is

stable for 6 months if stored in amber bottle and refrigerated. Solution discarded if precipitate was observed to form.

50 mL of each sample was mixed with 4 mL ortho-phosphate buffer, 2 mL of chloramin-T solution and 5 mL of barbituric acid solution. A drop of potassium ferry cyanide solution was added.

Nitrates

50 mL of each sample was added to a glass crucible and placed in a water bath for 2 hours to evaporate the water. The remaining precipitate was dissolved by adding 2 mL of concentrated diphenyl sulphonic acid, followed by 2 mL of DI water to reduce the concentration of the acid and up to 10 mL of 50 % NaOH to make the solution highly basic. If a yellow precipitate was observed upon the addition of NaOH, the sample was filtered, raised up to 50 mL with the addition of DI water and measured with a spectrophotometer at 540 nm.

Dissolved Oxygen

The samples were collected in 300 mL glass containers and filled slowly to the brim to prevent bubble formation. The sample was then immediately treated with 2 mL of sodium azide and 2 mL of manganous sulfate to precipitate out the oxygen. After collection, the sample was analyzed within 3 to 4 hours. Sulfuric acid was added to dissolve the precipitate. A portion of the sample was titrated with silver nitrate, starch was added as the indicator and titration was stopped when an endpoint of purple to clear was observed.

Biological Oxygen Demand

BOD measurements required that DO be performed for a sample on day 0, after collection and compared with DO measurements taken on day 3 after the sample had been incubated at 37C. Comparing the change in oxygen levels between these three days in the samples versus the controls allowed for the determination of the BOD. The calculation of BOD can be performed as follows:

$$BOD = \frac{((W_1 - W_2) - (C_1 - C_2)) \times 300}{(sample\ taken)}$$

Oil Sample Analysis

Soil samples were air dried or oven dried for several days before being ground up into a fine powder and sifted. Air dried powder was used for pH and conductivity tests. Oven dried powder was used for organic carbon, sulfate, and heavy metal analysis.

pH

10 g of air dried powder was dissolved in 50 ml DI water and shaken for at least 30 minutes. The pH reading was taken in similar manner as described for fluid samples.

Conductivity

The conductivity readings were taken using the same prepared soil samples for the pH tests.

Organic Carbon

25 g oven dried powder was mixed with 1N $K_2Cr_2O_7$ and 20 ml concentrated sulfuric acid. Then 200 mL DI water and 10 mL othrophosphoric acid and NaCl were added. 1 mL diphenylamine was used as indicator when titrating with 1N ferrous ammonium sulfate. The endpoint occurred when dark blue changed to bright green. Organic carbon content was then calculated according to the formula:

$$\% \ Org \ C = \left\{ 10 - (10 \times \frac{S}{B}) \right\} \times \frac{0.003}{0.77} \times \frac{100}{gram\ sample\ weight}$$

where S = ml of FAS titrated for sample, B = ml of FAS titrated for blank.

Sulfate

10 g soil was dissolved in 50 mL water and shaken for a few hours. The mixture was filtered into Nesslers tubes and filtrate subsequently reconstituted up to 100 mL with DI water. 1 to 2 drops HCl was added and heated to a boil. 4N $BaCl_2$ was added until a precipitate formed in the solution. NH_4OH was then added to bring the solution to a neutral pH. The neutral solution was then titrated with 0.25N $K_2Cr_2O_7$ and the endpoint was observed using the external indicator, $AgNO_3$. The sodium sulfate content was then calculated according to the formula:

$$Sodium\ Sulfate = 0.0177 \times 100(x - y), \qquad for\ 10g\ sample$$

Where x= ml N/4 –BaCl$_2$ added and y = ml N/4 potassium dichromate used in back titration.

Heavy Metals

Soil samples were dried in a drying oven and ground into fine powder with a mortar and pestle. 0.5 g powder soil was added to 25 mL DI water and 5 mL concentrated nitric acid. The solution was boiled down to 15 mL of liquid and resuspended to a volume of 25 mL in DI water. The samples were all analyzed by the GBC Avanta (Version 1.32) Atomic Absorption Spectrometer.

RESULTS

Interview

One family lived immediately adjacent to Lake Veerapura. 15 families lived north (downstream) of Veerapura Lake. Three families lived south (upstream) of Veerapura Lake. Out of the 19 families interviewed, 0 families were satisfied with the quality of water available to their households. 1 family expressed "partial satisfaction", and 18 families expressed "no satisfaction." 10 of the family representatives were female, and 9 were male.

The family living adjacent to Lake Veerapura was the only family to obtain drinking water from a bore well, which may or may not share the same aquifer as Lake Veerapura. 11 out of 14 families obtain drinking water from a Panchayati tanker, while the rest used a private tanker. All 3 families upstream of the lake used the Panchayati tankers as well.

No families reported "no taste" of drinking water. Of the families that explicitly responded to the question, all indicated that the water had a distinct taste. Most reported a salty taste. A majority of the interviewees reported the presence of white film or white precipitate in their drinking water.

In addition to the questionnaire answers, several of the interviewees mentioned illnesses occurring within the last four years that they believed to have been caused at least in part by the poor quality of water including: tuberculosis, muscle/nerve weakness, stomach ache, diarrhea, light fever, hair loss, and rash.

Evaluation of Effluent Samples

The effluent samples failed both the General Standards for Discharge of Environmental Pollutants and the Primary Water Quality Criteria for Various Uses Laid Down By CPCB Class E. The effluent samples were brown, , turbid and had a foul odor. Most noticeably, the pH values of the samples (mean=3.58, n=6) were well below the prescribed levels allowed by both standards.

Evaluation of Lake and Bore Well Samples

All the lake and bore well samples failed the ISO drinking water standards. Most notably, the total hardness (Lake: mean=9.462, n=8, Well: mean=13.503, n=8) and contributing ion constituents: calcium (Lake: mean=8.474, n=4, Well: mean=9.275, n=8) and magnesium (calculation only), exceeded permissible limits. However hard water doesn't appear to have adverse affects on human health.. Mildly hard water has been associated with a decreased risk of cardiovascular disease , , . But hard water does make the water less palatable to drink and can corrode storage containers.

The lake samples exceeded ISO turbidity standards. The bore well samples were not tested for turbidity because from observation they appeared to be clear. However the dissolved solids exceeded permissible ISO standards (calculation only). Dissolved solids exhibit a "mineral taste," in water and can corrode metal surfaces. They indicate a high level of dissolved matter that may or may not have harmful health effects in humans. However it may affect plant growth and agricultural irrigation.

Lake samples exceeded ISO permissible limits for sulfate levels (mean=73.3, n=8). Bore well samples exhibited high levels of chloride (mean=15.575, n=8) but were still within permissible limits. Both do not appear to cause significant health problems at the levels present in the samples collected.

Lake samples had high iron content (mean=0.313, n=8). Although high iron content may give water a bitter taste and stain laundry, it is not hazardous to human health.

Lake samples also had high levels of manganese (mean=0.433, n=4), which may cause disease in humans including liver damage. Manganese is not known to cause problems for agriculture or live-stock use. Manganese may cause brown stains in laundry and poor tasting water.

Summary of Listed, Measured Values						
	Effluent Samples		Lake Samples		Well Samples	
	Mean	N	Mean	N	Mean	N
pH (at 25°C)	3.58	6				
Total Hardness			9.462	8	13.503	8
Calcium (25 mL sample)			8.474	4	9.275	8
Sulfate (mg/L)			73.3	8		
Chloride (mg/L)					15.575	8
Iron (mg/L)			0.313	8		
Manganese (mg/L)			0.433	4		

CONCLUSION AND FUTURE WORK

The effluents released into the storm drain near the large industrial area are highly polluted. These effluents converge into streams that feed into Lake Veerapura and seem to have polluted the lake as well. COD and BOD values for the lake are high and heavy metals that were prominently represented in the effluents were also found in the lake. However, we were not able to establish a relationship between the pollutants in the lake water and the bore well water. This relationship has to be further investigated by studying the seepage of the pollutants into the soil. The drainage pattern of effluent and lake water, the topography of underground aquifers near the industrial area, the lake and Veerapura village need to be determined and combined with data from a larger sample of bore wells of varying distances from the lake in order to characterize how the pollution of the lake water can affect the quality of the well water.

This study provides us with preliminary evidence that helps characterize the extent of the pollution, the quality of the drinking water and provides us with clues as to which parameters to further investigate. We can conclude that the effluent samples are highly polluted and that the surface water in the area has become contaminated as a result. Further investigation needs to be performed over a long period of time make sure that the results are reproducible and to understand how the results could vary seasonally.

The relationship between the drinking water and any possible health effects mentioned by the villagers also needs to be further investigated. In interviews, the villagers spoke with such conviction about the illnesses they experienced after drinking water from the Veerapura area approximately three to four year ago. We were surprised to find that the contaminants present in the well water could not account for the aforementioned health effects but it is possible that other pollutants that were not tested for can account for the villager's statements Another study should be conducted to investigate the health of the villagers three years ago when the symptoms were manifested. The study should quantitatively determine the number of villagers who became sick, their distance from the water source, the water source they consumed, the type and severity of their illness, etc. Characterization of the health of the villagers three years ago will help us understand what factors could be adversely affecting the health of the villagers.

Our study should be used as a preliminary framework to guide further investigation of the area. Once the reproducibility of our results is verified it will be possible to use the results to protect the land near Veerapura and the health and livelihood of the residents of the area.

NOTES

To read additional appendix materials such as the interview questionnaire, photos of survey sites, and further documentation visit UMURJ.org.