A Practicum in Remediation of Shallow Large Bore Wells

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Thousands of rural Americans get their drinking water from wells that look like this:

What's inside of these wells can be repulsive. We have seen snakes, bats, a multitude of "bugs", termites, tree roots, transmission fluid, motor oil, trash such as bottles and baseball gloves, and often worms like the one in this picture that was about 6 feet down inside of a well:

Many families are drinking out of a sanitation nightmare. It is common practice for families to drink the water just like it comes from the well—without disinfection, treatment, filtration, or testing.

For low income families it is the only affordable source of water.

Can these wells be upgraded to become a sanitary source of drinking water?

Introducing the SAIF Water Committee

The SAIF Water Committee began in 1989 as an effort of many churches to help the hundreds of people in our area who still did not have indoor plumbing. The challenge now is to see if thousands of rural wells can be upgraded to prevent contamination.

We are located in Lancaster and Northumberland Counties of Virginia—a very rural area where the majority of homes depend upon private wells. SAIF Water has dug over 100 new wells and attempted to repair several hundred old wells. That experience has raised so many questions that we sought a grant from the Jessie Ball duPont Fund to study the problems of shallow wells in our area.

Our advisor from the Northumberland County Health Department, Environmental Health Specialist Rosalie Coultrip, our Well Technician Reverend John Bibbens, and our SAIF Water Committee field worker, Peggy Gaddy are available during the conference for questions. Our exhibit includes a video documentation of a well project prepared by Mrs. Coultrip.

The Big Gap in Public Health Policy

The best estimates we can find indicate that 3,486 homes in our two counties have water that is drawn from inadequately constructed wells. Prior to 1992 homeowners could site and dig their own wells without consulting the health department. Today, after the initial inspection of a new well, there are no requirements for monitoring a private well that serves less than 10 homes. In a country with national standards for safe drinking water, there is a huge gap in public health and safety because private wells are not regulated after their initial installation and many homeowners are woefully uneducated as to proper maintenance.

The Shallow Well – a valuable water source

Our large-bore wells, commonly referred to as "shallow wells", draw from the surficial aquifer. They are fed by rain and snow which is filtered by the soil. This is a renewable source of water. This type of well construction is used extensively in the United States and in developing countries.

Preservation of this water source in a sanitary fashion is important to our area because we do not have reservoirs, our artesian aquifers are extremely high in sodium, and our artesian aquifers are being drawn down about one foot a year by urban and industrial development in surrounding areas.

The Structure of a Shallow Well

The wells are less than 100 feet deep, usually ranging from 20-80 feet deep. Large cement curbs 24 to 48 inches in diameter are necessary because the groundwater flow is not strong enough in our area. As the well is being bored, the cement curbs 2 or 3 feet high are simply stacked on top of each other with each curb overlapping the curb below. The wells are essentially a mini-reservoir containing 6-20 feet of water. They are highly susceptible to contamination from sources on the surface such as animals, and septic systems.

Our efforts have focused both on sources of contamination and the pathways which allow contamination to enter a water well.

Shallow Well Studies in Virginia

Health Department Study. The Virginia Department of Health has conducted only one study of shallow wells—in 1983 prior to institution of construction standards for well drillers. Virginia has not conducted a study of whether shallow wells bored today according to Health Department specifications will be a safe source of drinking water. The Virginia Department of Housing and Community Development no longer approves construction of shallow wells and has restricted their programs to artesian wells.

Curran Study. In 1995 the SAIF Water Committee engaged a summer intern from Virginia Tech in a study of wells in Lancaster County. Analyses of water quality were generally good. However, of the 44 wells sampled 13 (30 percent) were positive for *E. coli* bacteria. That study caused SAIF Water to put high priority on installing pumps in wells where water was still being drawn by bucket and rope. Every hand drawn well had detectable levels of fecal coliform.

duPont Survey. In 2003 the SAIF Water Committee began a three-year study grant with a survey of 40 wells in Northumberland County which were selected to span the county's varying types of topography and represent three kinds of construction--ungrouted, grouted by hand, and grouted by a well driller. This was a selected sample, not a random sample. Water quality analyses were conducted by Virginia Tech. Evaluations included on-site inspections of the integrity of the well and environmental assessments. The survey was intended to identify areas for research. Questions regarding construction techniques were fielded via Internet to a wide variety of sources.

When two wells which used treatment systems are excluded from the data, **90 percent of the wells** (34 of 38) showed **detectable levels of total coliform bacteria**. **Sixteen wells (42 percent) had detectable levels of E. *coli* bacteria**.

Nitrate concentrations did not reach the level indicated as hazardous in the National Drinking Water Standards for adults (10 ppm-parts per million of milligrams per kilogram). However, nitrate was present in 31 of the 40 wells at a concentration that could cause health problems for infants.

Ongoing bacteria records. In addition to follow-up tests immediately after remediation of wells, the SAIF Water Committee has bacteria analyses on wells which were repaired up to 7 years ago. But consistent long-term follow-up is on the wish list for funding.

Kingston Study. In a recent sampling of one neighborhood with 8 wells—all wells failed total *coliform* screening, but none showed detectable levels of E. *coli* bacteria.

Watchdog Study. A special grant enabled SAIF Water to obtain virus screening of water samples through the University of Michigan. Twelve wells were sampled initially and 8 were sampled a second time. The samples were analyzed for fecal coliform, enterococci and coliphage. The university identified 4 wells of great concern for potential public health risk and advised alternative sources of water, boiling the well water, or installation of treatment systems.

Studies Needed. The studies above suggest that the most widespread issue for shallow wells is contamination by bacteria. There remains a need for careful scientific research to assist in developing protocols for remediation of shallow wells and to document the effectiveness of various repair techniques.

Well head Protection

In Virginia well drillers are required to install a protective grout (cement) down 20 feet for shallow bored wells. The annular space around the well is approximately 4 inches wide. Cement is usually used for shallow wells, while artesian wells are grouted with bentonite. The 20 foot rule of thumb is applied without regard to soil types and in actual practice, sometimes cannot be achieved. The 20 foot grout prevents water from entering the well before it is filtered by the soil.

Many older shallow wells have no protective sealing or grouting. Remediation is done by hand with a post hole digger which can only go down about 6 feet around the outside of the well. Then a crew member goes down the inside of the well and seals seams and leaks with cement down to the 20 foot depth.

Evaluating a Shallow Well - Three case studies

How do you approach remediation of a shallow well? First let’s look at three examples.

Well A is on a farm with wild and domestic animals often on and around the well. It was hand grouted in about 1994 with cement going down about 6 feet around the well and seams and piping were sealed inside the well to a depth of 20 feet. The well is roughly 40 years old and was probably dug by hand. Although nothing was done to the well in 2003 and 2004, laboratory analyses varied dramatically:
In June 2003 total coliform results were 579 MPN/100 ml and E. coli 48 MPN/100 ml.
In February of 2004 total coliform was 131 and E. coli zero.
In July of 2004 total coliform was 1046 and E. coli 11.
In September of 2004 no total coliform and no E. coli were reported in the water sample.
The owner is an asthmatic, and so chlorination is not advisable. Is it safe to wash your hands for dinner at this house?

Well B looks like a mess. The owner has thrown a board over the top. There are deep holes around it which act as draw downs for surface water. The pump pit is nearby. Nothing has been sealed inside the well. And yet laboratory reports show no E. coli and only 81 MPN/100 ml for total coliform bacteria.

Well C is owned by an elderly lady who is a heart patient with very limited physical strength. The soil on her property is not good enough to handle a septic system, so she is not allowed to have indoor plumbing. The SAIF Water Committee cleaned up the well and installed an outdoor faucet near her back door in 1996 and installed a vault privy so that sewage is now going into a tank instead of a pit dug in the ground. The old pit privy was only 70 feet from the well, but the water passed initial coliform bacteria screenings. She has recently purchased property next door which has land suitable for a septic system and is now asking for help to get the water pumped indoors before she is further disabled by knee surgery. A routine test of the well in September of 2004 showed total coliform bacteria count as > 2,419 MPN/100ml and E. coli 32.8 MPN/100 ml.. Possible sources of contamination include being only 20 feet from the highway drain ditch which is almost as deep as the grout for the well; an abandoned, junk-filled trailer about 20 feet from the well; the old pit privies; an ungrouted, unused well on the neighbor's property which is roughly 100 feet from the well she is using; and the possibility that bacteria grows easily in the well because not enough water is being used when water has to be hand carried.

Any consideration of remediation for a shallow well should include a thorough assessment of social and environmental factors, laboratory analyses, and inspection of the well structure to determine sources of contamination and pathways and entry points into the well. Laboratory analyses of follow-up samples are a necessity.

Common Pathways of Contamination

<u>Sampling errors</u>

It is very easy to introduce total coliform bacteria to a water sample by handling the bottle without disposable gloves, or drawing the water from an outside faucet or a kitchen sink with dirty dishes. SAIF Water has begun getting MPNs (most probable number) counts rather than pass/fail reports in an effort to judge whether there may be a sampling error, a need to rechlorinate, or an unsealed pathway for contamination.

The laboratory results may reflect plumbing problems rather than the condition of the water in the well unless the faucet is sterilized and water is run off to remove what has been standing in the plumbing system.

The University of Michigan requested that faucets be run for at least 15 minutes before taking samples. To be sure that you are sampling water from the well and not the plumbing, we recommend running off at least 50 gallons of water in order to empty the storage tank. Tanks in our area normally hold 12, 15 or 30 gallons of water. The water flow averages 4-5 gallons a minute. To determine the amount of time a faucet should be run, check the amount of time needed to fill a gallon with water and multiply by 50.

Several sources have suggested taking the sample from the faucet closest to the well. That is not necessarily the outside faucet. Depending on how the plumber routed the plumbing, the outside faucet could actually be at the end of the plumbing system. Mid-Atlantic Laboratories recommends the cold water faucet in the bathtub which usually does not have a strainer.

The well cap

The standard well cap specified by the Virginia Department of Health is a cement lid with shoe-box style overhang. However, the cap may not fit correctly, the owner may leave them ajar, or there may be chips out of the top curb which allow dirt and critters to enter at the well top. We found dozens of bugs and a snake in a recently bored well because the cap did not fit securely. We have put a seal under the cap by using Liquid Nails and ordinary household weather stripping. We have also used electrical duc seal, but recommend the weather stripping approach so that the owner can easily replace it if the well is opened for servicing.

The plumber and the Plumbing

Everything on a plumber's shoes goes down the well with him. Many plumbers do not chlorinate a well after they have opened it up and worked inside it. They may also assume that they only need to chlorinate if they have worked inside the well itself. Engineers at Midwest Plan Service recommend chlorination "anytime the source or system is opened for remodeling or repair." (p.55)

When the pipeline is installed, plumbers break a hole through the cement curb often leaving a jagged opening around the pipe where dirt can pour into the well. The pipeline may be installed inside a sleeve which goes through the curb. The sleeve should also be sealed on the inside around the pipeline.

Unsealed/ungrouted circumference

We do not yet have solid scientific evidence on the effectiveness of grouting an older well. But a wealth of experience is highly suggestive.

Our committee hired a contractor to put indoor plumbing in a home. A month after he finished the homeowner called because his water had turned muddy after heavy rains. The contractor did not grout the old well and surface water ran down the sides of the well entering at seams between the curbs close to the ground surface.

Our advisor from Water Systems Council tells of holes so deep around an old shallow well that it took ten bags of bentonite to fill them.

Irregularities in cement.

When cement is poured down the annular space of the well there are many opportunities for dirt to leave pockets in the grout. Rather than ordinary gravel as one would use for a driveway, we have been using a product called Crush and Run which is almost a cement mix and will harden.

Inadequate disinfection.

During the drought we had a well crew cleaning and deepening wells to try to get an emergency supply of water. Every well failed a coliform bacteria analysis and we were going back to chlorinate a second time. After about 10 wells, we felt it was cost prohibitive and just began chlorinating the second time without a lab test. Then we arrived at a well site just as the crew was chlorinating and noticed that the man was splashing most of the liquid bleach around the sides of the well. Very little got into the well water and the water level never came up to the area that had been bleached.

Homeowners in the country are very reluctant to use bleach lest their well water taste like city water. The SAIF Water Committee uses charts from the Environmental Protection Agency which indicate a gallon to two gallons of household bleach are needed for the amount of water in most of our wells. Even though we instruct the homeowners in how to do an annual disinfection, they may only use a teacup of bleach for 20 feet of well water.

Chlorine needs an undisturbed residence time to do its job. For this reason we have stopped using liquid bleach which needs at least 24 hours and begun using calcium hypochlorite crystals which require only 6 hours. It is much easier to get homeowner cooperation.

After the chlorine is put in the water well it must be run through every faucet in the home until the odor of bleach comes through. After a number of experiences with wells that failed to pass coliform bacteria screening after two or more chlorinations we have begun an additional procedure at the suggestion of Mid-Atlantic Laboratories. Water is run through the faucets a second time after the chlorine has been in the well for its appropriate residence time and the faucets are allowed to sit before beginning the process of running off the chlorinated water so that fresh water can enter the well.

It is very easy to get a false reading by sampling the well too soon after chlorination. Mid-Atlantic Plan Service recommends waiting a week after pumping the chlorinated water out of the well and using the water for a week for everything except drinking before taking the water sample. (p.56) The SAIF Water Committee now uses the chlorine test strips made for swimming pool checks. Waiting until a test strip shows no chlorine normally takes at least a week and sometimes two.

We are still researching a number of questions on chlorination which are appended.

Common Sources of Contamination

Common sources of bacterial contamination include domestic and wild animals, septic systems and pit privies, standing water from low usage rate, cemeteries, neighboring wells, agricultural operations, trash and old vehicles sitting near the well, and the pump pit.

Home heating oil tanks

When a home heating oil tank leaks, the ground around the well becomes saturated with the oil. Often the only solution is to abandon the well and dig a well that does not draw from the surficial aquifer. We do not attempt to repair a well with this type of problem, but call in technicians who are trained for oil spills.

A slow leak in the oil line under a neighbor's home gradually soaked the ground and made its way into a well The picture shows a jar of water from the well with the kerosene rising to the top. It was caused by a slow leak in the oil line under a neighbor's house with no detectable odor in the home. The Department of Environmental Quality estimated that the kerosene had been leaking for about a year before it reached the stage where the homeowners noticed a funny taste in the water and called for a water test. By this time we were able to pour well water on the ground and watch it burn.

Summary

Thousands of rural citizens are currently outside the protection of our National Drinking Water Standards.

- At this point there is a great need for research to document whether commonly used methods for remediation of shallow wells are adequate to insure a safe supply of drinking water.
- Research is needed to verify the safety of drinking water in new shallow wells dug with modern specifications.
- A protocol for thorough assessment of environmental factors in addition to well construction problems is crucial.
- Focus must be placed on plumbing as a source of bacterial growth.
- Sampling techniques must be carefully scrutinized and documented.
- There is a vast need for public education in maintenance of water wells.
- Information on sanitation procedures for wells needs to be disseminated to plumbers, persons who "clean" wells, certification boards for well drillers, health department sanitarians and other water professionals as well as homeowners.

A reliable method of withdrawing water from the surficial aquifer would preserve a valuable and renewable source of water.

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APPENDIX A – Chlorination Questions

For many years we have used a widely distributed EPA chart to disinfect private, large-bore wells. A number of questions have arisen.

1. The chart was published prior to Milwaukee's experience with cryptosporidium. Have the amounts been validated or changed recently?
   (Manual of Individual and Non Public Water Supply Systems, EPA Office of Groundwater and Drinking Water, EPA - 570/9-91-004, May 1991.)

2. Homeowners and even experienced plumbers are very reluctant to use the amount of chlorine stipulated in the chart because the odor lingers for weeks after the well is drained and they don't want to have water that tastes like city water.

   Sometimes a well has passed a total coliform test when much less chlorine was used than the chart indicates. Is it possible that total coliform is not screening for some kinds of bacteria or protozoa and the well water only appears to be safe?

3. On some occasions a well does not pass total coliform tests even though all structural problems have been repaired and the system has been chlorinated twice. We suspect that the problem may be in the plumbing and wonder if there are better directions for disinfecting the plumbing. Directions distributed by the Virginia Cooperative Extension Service are different from some we have received from a private laboratory.

4. It is our understanding, which we have not been able to document, that use of dry crystals of calcium hypochlorite rather than liquid chlorine bleach requires less residence time. This would help greatly with the fact that homeowners find it difficult to leave the water undisturbed for a full 24 hours. Can you verify this for us and give us an indication of how many hours we should be allowing the calcium hypochlorite to stand undisturbed in the well?

5. State regulations require a public water system to take three samples from different locations in the system for total coliform bacteria. Because of cost, private well owners have been allowed to take only one sample to determine potability. That sample is often taken very soon after chlorination. We suspect that we may getting a false picture of the health of the water system.

6. Do you have any information on health related results if homeowners fail to chlorinate annually? We are involved in many efforts at public education and have not found an effective way to convey the importance of this standard.

7. Shock chlorination is usually the only method used for private wells here. There is also a high incidence of asthma. Chlorinating a water system can lead to asthma

attacks. Is there an alternative, comparable disinfection agent short of installing equipment for ongoing treatment and filtration?

8. The Center for Disease Control's Safe Water program for developing countries recommends setting up a separate product and label for disinfecting drinking water to avoid the homeowner's reluctance to use bleach and the variations in quality of household bleach products. Is there such a product available in this country?

9. Since some wells have organic matter in them such as tree roots and leaves, should we be cleaning these out before adding chlorine? The typical well here gets an annual chlorination of 1-2 gallons in 10-15 feet of water. There are, however, some homeowners who add chlorine regularly in much smaller amounts.

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