2010

MONITORING AND MAINTENANCE PROGRAM FOR RESIDENTIAL WELLS USED FOR GROUNDWATER ABSTRACTION IN LAGOS STATE, NIGERIA

http://www.hobotraveler.com/2006/10/boukombe-boukoumbe-benin.html
Well in Africa

Omogbemiga Talabi

MONITORING AND MAINTENANCE PROGRAM FOR RESIDENTIAL WELLS USED FOR GROUNDWATER ABSTRACTION

IN LAGOS STATE, NIGERIA

by

Omogbemiga Adepitan Talabi

ARIZONA STATE UNIVERSITY

December 2010

Table of Contents

Page

LIST OF TABLES

LIST OF FIGURES

Groundwater Monitoring Program

The methodology of this groundwater monitoring plan is partially based on Section 4 of the World Health Organization (WHO) publication titled, "**Protecting Groundwater for Health**" (2006) and **Guideline to Drinking Water Quality** (GDWQ), third edition, volume one (WHO 2004). The development of GDWQ came from various international conferences that recognize the important need for access to safe drinking water to be part of an international agenda. The current GDWQ explains necessary steps in ensuring drinking water safety. It includes minimum procedure requirements, specific guideline values and discussion of how these requirements are intended to be used.

This is a groundwater monitoring program for residential wells in the Lagos State metropolitan area. This plan identified necessary agencies and stakeholders that would be involved in implementing an effective monitoring program. The plan established necessary templates and sampling and analytical guidelines needed during the course of the program. It also established community awareness plan needed in educating the communities within Lagos metropolitan area.

Identified Stakeholders

The stakeholders identified were:

- The Lagos State Water Corporation which has been given the right by Federal status to protect citizens from water quality problems.

- Individual local government areas
- Higher educational institutions that may provide necessary data and help in laboratory testing for some of the parameters tested during routine monitoring

The Lagos State Water Corporation

The corporation is charged to provide potable water to the citizen of Lagos State. The mission of the corporation is to:

- "To provide safe drinking water in sufficient and regular quantity in Lagos State."
- "To maintain good quality service by collecting enough revenue to sustain effective operational expenses."
- "To carry out functions to meet customer's expectation by planning for sustainable growth and overall progress of the corporation."
- "To promote good community health by ensuring Customer satisfaction."

(Lagos State Water Corporation, 2009)

Individual Local Government Areas

Identified below are individual local development areas that are given the duty to regulate and enforce local regulatory status as it relates to the sustainability of the people within their communities. Lagos State was divided into five Administrative Divisions (AD), which are further divided into twenty Local Government Areas (LGA) and thirty seven Local Council Development

Areas (LCDA). Sixteen of the twenty LGAs are within the Lagos metropolitan area. These are shown in Table 1 and Figure 1.

Table 1. Local Government Areas

Badagry Division	Epe Division	Ikeja Division	Ikorodu Division	Lagos Division
Ajeromi-Ifelodun	Epe	Agege	Ikorodu	Apapa
Amuwo-Odofin	Ibeju-Lekki	Alimosho		Eti-Osa
Badagry		Ifako-Ijaiye		Lagos Island
Ojo		Ikeja (capital of Lagos State)		Lagos Mainland
		Kosofe		Surulere
		Mushin		
		Oshodi-Isolo		
		Somolu (aka Shomolu)		

Figure 1. Lagos State Metropolitan Map Showing Local Government Areas

The responsibilities for monitoring water quality and adhering to the requirements of the program are proposed to be vested in:

1. Qualified water quality managers;
2. Local agencies that show interest in building healthy communities and the ability to gain the required knowledge and capacity.

Staffs of local agencies that will be involved in water monitoring will undergo specific structured training. The training will focus on areas of water quality monitoring that are not currently run effectively by the agencies. Accreditation requirements of water quality managers needed to carry out this function will be provided. The accreditation and structured training will be performed by the University of Lagos Water Quality department.

Higher Educational Institutions

In Lagos, there are four proposed major institutes of higher education that can provide necessary data and help in laboratory testing of some parameters used in routine monitoring. These institutions are

- University of Lagos;
- Yaba Polytechnic;
- Lagos State Polytechnic;
- Lagos State University.

There are also research laboratories established by the World Health Organization (WHO). Samples would be collected by field staff and sent

to one of the four institutions depending on turnaround time of analytical results.

Identified Potential hazards and hazardous environment

Part of this program entailed identifying potential hazards and hazardous environments; this would help in effective evaluation of the monitoring plan process. The initial step in identifying potential hazardous environment was to take pictures of the entire well area for each home or facility inspected. This would include pictures of observable potential causes of water quality problems in the groundwater abstraction area. It should be noted that taking pictures in certain areas of Lagos could be a problem due to religious and cultural reasons. For example, areas with high population of Muslims would not allow men who are not members of their clan to enter their area. However, agreements were put in place through the local governments identified above to allow photography access to these areas. In certain areas, a schematic diagram clearly identifying water quality problems would be sufficient enough if photographs were not available. Some of the conditions that should be noted in the report on initial potential water quality problems are:

- Location of wells relative to sanitary waste facilities;
- Location of wells relative to industrial facilities (if present);
- Maintenance of tools for water abstraction;
- Potential for contamination due to poor construction or damage to the wells;

- Potential for contamination introduced by buckets;
- Potential for contaminated surface water to enter boreholes;
- Leaching of microbial contaminants into an aquifer;

The next step of developing a monitoring program was to call for a person to inspect the groundwater well currently being used and ask questions of the local residents about how the water tastes and if there are any possible odors or unusual appearances. The person conducting the monitoring would also note if there were any reported adverse events like storms, landslides or bushfires or industrial spills that had taken place in the past, events that might impact the quality of the well water. Another step was to identify seasonal issues that might affect water quality. Lagos State usually experiences about three months of heavy rainfall, which usually results in flooding in most areas due to ineffective drainage systems or lack of drainage systems.

Another task would be to inspect tools used for water abstraction and storage (i.e., tanks) and observe possible contamination. Information collected would be recorded in the initial site characterization form provided for this monitoring program. After looking at various deficiencies or maintenance issues, recommendations would be made in regards to possible solutions. The template on the next page would be used to collect necessary information in characterizing potential well site issues:

INITIAL SITE CHARACTERIZATION for RESIDENTIAL WELLS in LAGOS NIGERIA

Date: _____

Rent ☐ Landlord (owner) ☐

Address: _____

Local Government Area: _____

Number of wells

Boreholes ☐ Dug wells (Konga) ☐

Location of wells

- Front of the Building ☐
- Back of the building ☐
- Side of the building (specify North, South, West or East) ☐

Location of septic tanks

- Front of the Building ☐
- Back of the building ☐
- Side of the building (specify North, South, West or East)

Distance between wells and septic tanks (circle appropriate distance)
< 10 meters
>10 meters but < 20 meters
> 20 meters

Is the well(s) entrance constructed with (CONCRETE)/ (NO CONCRETE)

Pit Latrines (**shalanga**) (YES)/ (NO)

How are the buckets and ropes used for drawing water cleaned (sanitized)?

Mark (x) Appropriate Box:

CHARACTERISTICS	**YES**	**NO**
Turbid, cloudy or dirty		
Color and/or organic odor		
Salty taste		
Bitter taste		
Difficulty forming lather with soap		
Blue stains (corroded copper pipes)		
Rotten egg smell – H2S		
Scaling on pots or kettles (indicator of hardness)		
Any Storm events		

Collected by:_____.

Reviewed by:_____.

Figure 2: Site Characterization Form

Biological and Chemical hazards

Most of the potential hazards associated with well water abstraction in Lagos State are E. coli, metal and nitrates (Egwari and Aboaba, 2002). However, in commercial areas in Ikeja (Ikeja division) where the majority of industrial and pharmaceutical industries exist, other inorganic and organic compounds common to the industry may be present and would be monitored and evaluated. Guidelines were created to help the field staff during the course of monitoring and data collection at various sites to identify potential sources of contaminants based on the outcome of analytical tests performed. Below are the guidelines provided for staff use.

Typical Water Quality Concerns, Source of Contamination and Their Potential Impact on Consumers

QUALITY CONCERNS	SOURCE OF CONTAMINATION	IMPACT ON CONSUMERS
Pathogens	Contaminated water containing fecal matter entering the aquifer. Possible contamination of the water after water collection due to poor sanitation and hygiene practices.	Impact can vary from mild gastroenteritis to severe and sometimes fatal diarrhea, dysentery, hepatitis, cholera or typhoid fever.
Nutrients, algae and algal toxins	Examples are nitrogen and phosphorus from farming which might result in high levels of algae in water.	Impact on organ-specific diseases, neurological, behavioral disorders reproductive or developmental issues, carcinogenic or mutagenic diseases.

QUALITY CONCERNS	SOURCE OF CONTAMINATION	IMPACT ON CONSUMERS
Metals	Leaching of metals (e.g. arsenic, mercury) from natural rock and soil formations. Leaks from industrial waste dumps or pipes.	Organ-specific diseases, neurological, behavioral disorders reproductive or developmental issues, carcinogenic or mutagenic diseases.
Pesticides, herbicides and insecticides	Leaks into boreholes or wells from abandoned containers near water abstraction areas. Farming close to well and boreholes.	Impact on organ-specific diseases, neurological, behavioral disorders reproductive or developmental issues, carcinogenic or mutagenic diseases. High dose might result in acute or chronic effect.

QUALITY CONCERNS	SOURCE OF CONTAMINATION	IMPACT ON CONSUMERS
Industrial chemicals, fuels and organic compounds	Wastewater discharges and spills from industries, and leakage from underground fuel storage tanks into the aquifer. Dumping of chemicals in landfill	Impact on organ-specific diseases, neurological, behavioral disorders reproductive or developmental issues, carcinogenic or mutagenic diseases. High dose might result in acute or chronic effect.
Aesthetic parameters ▪ Turbidity ▪ Color ▪ Salt (TDS or EC) ▪ Temperature/pH Hardness/ ▪ Alkalinity ▪ Iron, manganese or aluminum	A wide range of sources, both natural and from human activities. Color may result from presence of iron and manganese, and salt may result from salt intrusion from the ocean near Lagos State.	Bad taste, odor or appearance. Possible iron poison.

Table 1. Typical Water Quality Concerns (Australian Government, 2005).

Below are additional tables used to collect information on observed situations during the course of initial sites characterization, where possible groundwater contamination might be occurring. Mark appropriate box base on your observation.

Activities and Practices that Pose Risks to Water Quality

(Please mark appropriate box)

High risk activities	**Pathogens**	**Nutrients leading to algae taste, odor and toxins**	**Metals**	**Pesticides Herbicides Insecticides**	**Industrial chemicals, fuels and organic compounds**	**Aesthetic parameters**
Incorrect or inadequate construction of the groundwater bore, allowing surface water ingress either at the bore site or through porous soil or rock						

High risk activities	Pathogens	Nutrients leading to algae taste, odor and toxins	Metals	Pesticides Herbicides Insecticides	Industrial chemicals, fuels and organic compounds	Aesthetic parameters
Leaching of metals (for example arsenic, mercury) from natural rock or soil formations						
Leaks from underground fuel storage tanks						
Sewage discharge (even if treated) at or near the well area						

High risk activities	Pathogens	Nutrients leading to algae taste, odor and toxins	Metals	Pesticides Herbicides Insecticides	Industrial chemicals, fuels and organic compounds	Aesthetic parameters
Houses with domestic waste leak at the well area						
Intensive agricultural at or near the well area						
Recontamination of the well prior to use either during water storage or distribution						

High risk activities	Pathogens	Nutrients leading to algae taste, odor and toxins	Metals	Pesticides Herbicides Insecticides	Industrial chemicals, fuels and organic compounds	Aesthetic parameters
Domesticated animals and animal husbandry around the well site						
Leaks from chemical processing industry waste dumps in the groundwater recharge area						
Storm water from villages (particularly where wastewater capture, treatment and sanitation are poor) entering the borehole and wells						

Figure 3. Activities and Practices that Pose Risks to Water Quality (Australian Government, 2005).

Characteristics that Indicate the Presence of Potential Water Quality Problems

Characteristics	Pathogens	Nutrients leading to Algae taste, odor and toxins	Metals	Pesticides Herbicides Insecticides	Industrial Chemicals, fuels and organic compounds	Aesthetic parameters
Turbid, cloudy or dirty, particularly after storms	x					x
Color and/or organic odor	x	x	x			x
Salty taste						x
Bitter taste			x		x	x
Difficulty forming lather with soap						x
Blue stains (corroded copper pipes)			x			
Rotten egg smell – H_2S						x
Scaling on pots or kettles (indicator of hardness)			x			x

Figure 4. Presence of Potential Water Quality Problems Indicator Form (Australian Government, 2005).

Basic Observed Quality Parameters and their Implications

Parameters	Implication for water quality
E. coli (Escherichia coli)	Indicates fecal contamination of the water supply. Possible presence of pathogens.
Coliforms	These should not be present after disinfection. Their presence after treatment can indicate that the disinfection was ineffective and that there is a risk of pathogens.
Turbidity	Shows possibility of microorganisms if above 1 NTU
Color	Indicates possibility of organic or inorganic materials in the water, which can interfere with disinfection and produce harmful disinfection by-products. May also indicate the presence of iron or manganese.
Salts	Generally makes the water unpalatable or unpleasant to drink.
Hardness	Can affect treatability of the water and the ability of the water to lather.
pH	Should be in the neutral range (6.5–8.5). At higher pH, scaling may occur if hardness is high. If below 6.5, water can be corrosive and attack metals.
Metals – arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc	Can be harmful to humans and animals if consumed.
Metals – iron or manganese	Can cause brown or black water, staining and coloration of laundry and baths, sinks and an iron or bitter taste.

Figure 5. Basic Observed Quality Parameters and their Implications (Australian Government, 2005).

Analytical guidelines

Based on initial potential hazards and hazardous environment identification, private owners of wells would be advised to monitor their wells every six months for the first two to three years and annually for subsequent years. The frequency of testing might vary depending on new activities taking place within the well sites.

Qualified staff or laboratory personnel would perform sample collection. Efforts would be made to incorporate specified sampling techniques as part of the training for the local staff that would be implementing this program.

At a minimum, wells would be tested for coliform (E.Coli) bacteria, nitrates, hardness and turbidity. Separate sample containers would be used for bacteria testing. Below are sampling requirements for various parameters.

Table 2. Sampling

Parameters	Sample volume/container	Maximum contaminants level Goal (MCLG)	Implication for water quality
E. coli (Escherichia coli)	100ml/100ml container	zero	Presence of pathogens (fecal waste)
Turbidity	50ml/50ml	< 1.0 NTU	Possible presence of microorganism
Color	100ml/100ml container		Generally indicates organic material in the water.
Hardness	100ml/100ml container	<1000	Can affect treatability of the water and the ability of the water to lather.
pH	100ml/100ml container	6.5-8.5	At higher pH, scaling may occur if hardness is high. If below 6.5, water can be corrosive and attack metals.
Nitrates	100ml/100ml container	10ppm	High levels of Nitrates can cause serious illness and death, especially in infants

Sample collection Protocol

Sampling Check list:

Below are items that would be needed to take good representative samples of water from wells:

- ☐ Bottles
- ☐ Gloves
- ☐ Reagents and test strips or vials
- ☐ Bleach solution

☐ Ice chest and ice

☐ Labels

☐ Indelible markers

☐ Sample collection buckets

Before sampling, tools needed for sample collection would be sanitized. Prior to coming to the site, the sample collection bucket and any tools that might get in contact with the sample would be placed in bleach solution for two hours. These tools would then be removed and placed in a plastic bag.

Bleach solution:

Bleach solution for sanitizing the tools can be prepared by buying 6.0% sodium hypochlorite household bleach from the store and adding about half a cup of the solution to 1 gallon of water.

Labeling:

Labels would be prepared with the following information:

- Sample date
- Sample time
- Area location sample number
- Location of the sample (use household address)
- Analysis and the sampler's initials

Each label would be placed on a container before sampling. Sampling would preferably be done early in the morning. This is when there are fewer activities around the wells, thus reducing the possibility of external contamination. It would be essential to make sure the area around the well site was kept clean. If possible a 1:10 dilution of the bleach solution would be used to rinse the area.

The sanitized bucket would be removed from the bag and about 1 gallon of groundwater would be withdrawn from the well. The water would be passed into each container needed for the recommended analysis. Adequate sample documentation and information would be provided as required. All collected samples needed to be transported to laboratory would be in an iced cooler at 4 degree Celsius.

Quality Assurance:

This would include documentation, reporting, and record keeping in relation to data collected on a particular site.

A log book would be maintained for recording the following:

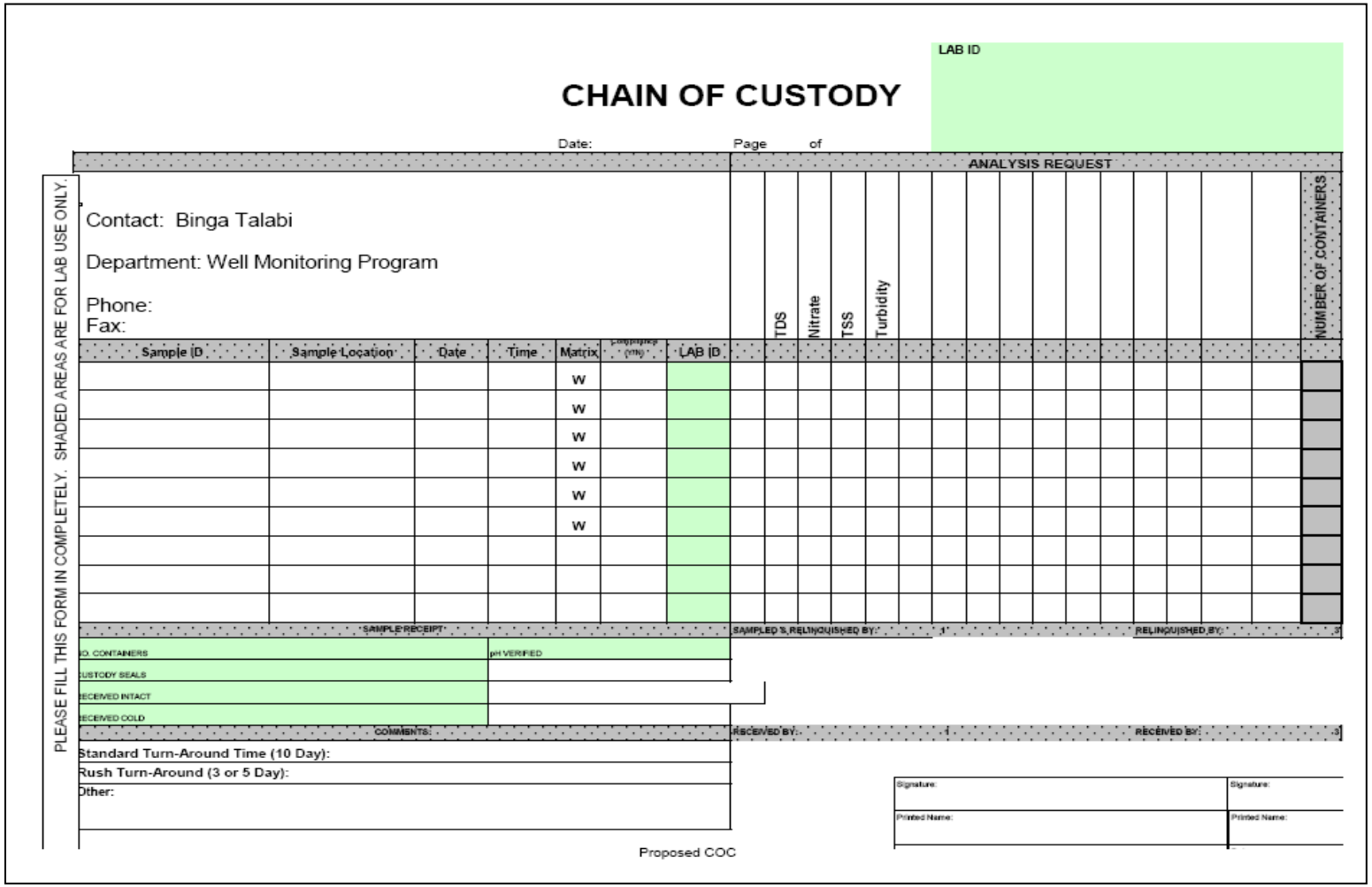
- The unique sample number
- The location where the sample was collected
- The date and time the sample was collected
- The free chlorine residual
- The initials of the sampler

- The name of the laboratory the sample was delivered
- A list of the analyses requested for the sample

Chain of custody

Chain of custody would include the following:

- Unique sample number.
- Date sample was collected.
- Time sample was collected.
- Location where sample was collected.
- Analyses required.
- Name of the person collecting the samples.
- Name of who submitted and received the sample with their signatures
- Date/time of sample was submitted.



LAB ID

CHAIN OF CUSTODY

Date: Page of

PLEASE FILL THIS FORM IN COMPLETELY. SHADED AREAS ARE FOR LAB USE ONLY.

Contact: Binga Talabi

Department: Well Monitoring Program

Phone:
Fax:

ANALYSIS REQUEST

Sample ID	Sample Location	Date	Time	Matrix	Composite (Y/N)	LAB ID	TDS	Nitrate	TSS	Turbidity	NUMBER OF CONTAINERS
				W							
				W							
				W							
				W							
				W							
				W							

SAMPLE RECEIPT | SAMPLED'S RELINQUISHED BY: 1 | RELINQUISHED BY: 2

NO. CONTAINERS | pH VERIFIED

CUSTODY SEALS

RECEIVED INTACT

RECEIVED COLD

COMMENTS: | RECEIVED BY: 1 | RECEIVED BY: 2

Standard Turn-Around Time (10 Day):

Rush Turn-Around (3 or 5 Day):

Other:

Signature:	Signature:
Printed Name:	Printed Name:

Proposed COC

Figure 6. Example of Chain of Custody Form

Community Awareness Plan

In order to effectively manage this monitoring program, staff would provide educational materials for community awareness that would be incorporated in the monitoring plan. This would address some of the possible questions of community participants and provide solutions needed to provide safe drinking water. The Questions and Answers template below would be used to educate the community on the need to have safe drinking water. This would be distributed within the local government area.

Table 3. Well Water Awareness Q&A

Well Water Awareness (Questions and Answers)
Question: What is well water?
Answer: This is water stored in the subsurface of the earth between grains of sand or other sediments or in fractures of rocks.
Question: If I don't have well water, then why should I worry about contamination?
Answer: Whether you have your own well or not, the water that is sold on the streets of Lagos all comes from the ground. Contamination can affect the water you drink.
Question: How does well water get to the surface?
Answer: Well water is an important component of the hydrologic cycle. Groundwater is pulled to the surface through dug wells (Konga) which are holes in the ground that are dug by shovels or jackhammers or drilled by drill machine. Another method to get water is through boreholes (deep wells). These are constructed in soil through the process of mechanical drilling.
Question: If the water is underneath the ground, it should be safe and of high quality, should it not?
Answer: In general, yes. Well water is susceptible to contamination from a number of sources, mostly due to human activities. Sources of contaminants might be malfunctioning pit latrines, septic tanks or landfills. With time, pollutants penetrate the ground and can mix with groundwater, thus polluting valuable sources of drinking water.

Well Water Awareness (Questions and Answers)

Question: Is well water safe for babies?
Answer: It depends on the level of contaminants in the water. A chemical called nitrate is one of the chemicals in water that, at high enough concentrations, can create serious danger to babies. Our soil contains small levels of nitrates. However, because of human activities like farming which involves the use of fertilizers, the levels of nitrate have been shown to have increased in groundwater. According to the World Health Organization (WHO), babies under six months old who drink water with nitrates may suffer from lack of oxygen, where the blood cannot carry enough oxygen throughout their bodies. This condition can be serious and can sometimes even result in death. If excessive nitrates is present, then boiling the water will only makes the problem worse. When nitrate-contaminated well water is boiled to make baby formula, the boiling concentrates the nitrates in the water and increases the health risk to the baby.

Question: How do we protect ground water?
Answer: We can protect our groundwater by making sure that our activities do not result in groundwater contamination. We need to use the currently established monitoring plan for wells to determine tests needed in order to provide safe drinking water. These tests should be conducted at least once a year.

Source: Kentucky Division of Water, http://www.water.ky.gov/gw/GWB-GW_awareness.htm

References:

Australian Government. (2005). *Safe water guide for the Australian aid program 2005, A framework and guidance for managing water quality*. Australia: Australian Agency for International Development. Retrieved from www.ausaid.gov.au

Adeyemi ,O., Oloyede, O. B., Oladiji, A. T.(2007). *Effect of Leachate-contaminated Groundwater on the Growth and Blood of Albino of Rats.3 (2*), The Internet Journal of Hematology. Retrieved from http://www.ispub.com/ostia/index.php?xmlPrinter=true&xmlFilePath=journals/ijhe/vol3n2/albino.xml

African Water Development Report (2006). *Governing Water Wisely*. Retrieved 08/02, 2010 from http://pacificwater.org/userfiles/file/IWRM/Toolboxes/institutional%20reform/Governing%20Water%20Wisely.pdf

Center for Diseases Control and Prevention. (2006). *Healthy housing reference manual; rural water supplies and water-quality issues.* Retrieved September 4, 2009, from http://www.cdc.gov.ezproxy1.lib.asu.edu/nceh/publications/books/housing/cha08.htm

City of Scottsdale Water Quality Lab (2002). *Coliform Rule Site Sampling Plan.* Standard Operating Procedure.

Down to Earth Magazine. (2004). *Poor laws and regulations and lack of coordination between regulatory bodies worsen the water crisis*. Retrieved 07/30, 2010 from http://old.cseindia.org/dte-supplement/industry20040215/just-use.htm

Egwari, L., and Aboaba, O. (2002). *Environmental impact on the bacteriological quality of domestic water supplies in Lagos, Nigeria*.*36*(4), 513-520. doi:10.1590/S0034-89102002000400019. *Rev. Saúde Pública [Online], 36*(4), 513-520-520. Retrieved from http://www.scielosp.org/pdf/rsp/v36n4/11772.pdf

Federal Republic of Nigeria (2000). *Water Supply and Sanitation Interim Strategy Note*, 29-30. Retrieved from

http://siteresources.worldbank.org/NIGERIAEXTN/Resources/wss_1100.pdf

Federal Republic of Nigeria (2000). *Water Supply and Sanitation Interim Strategy Note*, 4-5. http://siteresources.worldbank.org/NIGERIAEXTN/Resources/wss_1100.pdf

Federal Republic of Nigeria (2000). *Water Supply and Sanitation Interim Strategy Note. Small town water supply sanitation*, 8-9. http://siteresources.worldbank.org/NIGERIAEXTN/Resources/wss_1100.pdf

Groundwater and Surface Water. Retrieved 08/24, 2008, from http://www.historyofwaterfilters.com/ground-surface-water.html

Groundwater Management Advisory Team (2006). *Groundwater Resource Management.* Retrieved 10/03/2010 from http://siteresources.worldbank.org/EXTWAT/Resources/4602122-1210186362590/GWM_Briefing_1.pdf

Gleick, P. H. (1996). Water resources. *In Encyclopedia of Climate and Weather*, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823. (Extracted from USGS)

Hall, D. J. (2006). *Water and Electricity in Nigeria*, 6-7. Retrieved from http://www.World-psi.org

Howsam, P. (1993). *Cost-effectiveness of monitoring and maintenance options associated with groundwater abstraction*. Retrieved from http://www.lboro.ac.uk/well/resources/consultancy-reports/task0065/pdf/r5478.pdf

Kuruk, P. (2004) *Customary Water Laws and Practices*: NIGERIA. Retrieved from http://www.fao.org/Legal/advserv/FAOIUCNcs/Nigeria.pdf

Lagos State Water Corporation (2009), *Mission Statement*. Retrieved 9/30/2010, from http://lagoswater.org/our_mission.php

Okoye, J. K., and Priscilla,M, (2007). *Background study on water and energy issues in Nigeria to inform the national consultative conference on dams and development*. Retrieved from http://www.unep.org/dams/files/nigeria_final_report_on_background_study_22_may_07.pdf

Ongley, E.D. (1994). *A Integrated Measures to Overcome Barriers to Minimizing Harmful Fluxes from Land to Water*, 23-30. Retrieved from http://www.gems-water.org/freshwater_assessments/pdfs/global_water_pollution.pdf

National Geographic. *People and place.* Retrieved 8/30, 2008, from http://travel.nationalgeographic.com/places/cities/city_lagos.html

Nigerian Industrial Standard (2007). *Nigeria Standard for Drinking Water Quality*.

http://www.unicef.org/nigeria/ng_publications_Nigerian_Standard_for_Drinking_Water_Quality.pdf

Nigeria Water Resources Decree 1993 (Decree No. 101) (1993). Retrieved 12/26, 2009 from http://74.125.47.132/search?sourceid=navclient&ie=UTF-8&rlz=1T4DELA_enUS334US335&q=cache:http%3A%2F%2Ffaolex.fao.org%2Fcgi-bin%2Ffaolex.exe%3Frec_id%3D003713%26database%3DFAOLEX%26search_type%3Dlink%26table%3Dresult%26lang%3Deng%26format_name%3D@ERALL

North Carolina Water Quality (2007). *How to Disinfect Your Water Well*. Retrieved from http://h2o.enr.state.nc.us/aps/gpu/documents/WaterWellDisinf_2007.pdf

North Carolina Water Quality (2008). *Water Wells, Drilling and Construction Standards*. Retrieved from http://h2o.enr.state.nc.us/wc/documents/WaterWell_rev2008-1.pdf

Roumasset, J.A., and Wada, C.A. (2010). *Optimal and Sustainable Groundwater Extraction*. *Sustainability* 2010, *2*, 2676-2685; doi:10.3390/su2082676. Retrieved 10/03/2010 from http://www.mdpi.com/2071-1050/2/8/2676/pdf

Rogers, P. (1998). *Role of Government in Regulating Industrial Water Activities*. Retrieved 08/18/2010 from http://www.un.org/documents/ecosoc/cn17/1998/background/ecn171998-bp16.htm

Schmoll, O., Howard, G., Chilton, J., & Chorus, I. (2006). *Protecting groundwater for health*: Managing the quality of drinking-water sources. [World Health Organization]

Schmoll, O., Howard, G., Chilton, J., & Chorus, I. (2006). *Protecting groundwater for health: Managing the quality of drinking-water sources*. [World Health Organization]

Shah, T., Molden, D., Sakthivadivel,R., Seckler, D. (2000). *The global groundwater situation: Overview of opportunities and challenges.* Retrieved 10/03/2010 from http://www.irc-eh-field-guide.com/EH_PORTABLE_LIBRARY/EH%20KEY%20REFERENCES/WATER/Ground%20Water/Global%20Groundwater%20Situation%20(IWMI).pdf

Sonou, M. (1997). *Low-cost Shallow Tube Well Construction in West Africa*, 157-168. Retrieved from http://webcache.googleusercontent.com/search?q=cache:L2svuXDJpTkJ:www.fao.org/docrep/w7314e/w7314e0v.htm+Low-cost+shallow+tube+well+construction+in+West+Africa,+M.+Sonou&cd=1&hl=en&ct=clnk&gl=us

UNICEF publication. (1999).*The risk to groundwater supplies from on-site sanitation*. *Waterfront* , 16-18.

USGS. *Effects of Human Activities on the Interaction of Ground Water and Surface Water*. *Circular 1139*, (Part 2), 22. Retrieved from http://pubs.usgs.gov/circ/circ1139/pdf/part2.pdf

USGS (2009). *The water cycle*. Retrieved 03/01/2010 from http://ga.water.usgs.gov/edu/watercyclesummary.html

United Nations. *Economic Aspect of Sustainable Development in Nigeria*. Retrieved 08/04, 2010 from http://www.un.org/esa/agenda21/natlinfo/countr/nigeria/eco.htm

United Nations, *Johannesburg Summit (2002) Country Profile, Nigeria*. Retrieved from http://www.un.org/esa/agenda21/natlinfo/wssd/nigeria.pdf

UNICEF publication. (1999).*The links with sanitation, hygiene, water and environment*. Water front, issue 13, 1-28. Retrieved from http://www.unicef.org/spanish/wash/files/wf13e.pdf

UNESCO publication (2003). *Executive Summary, Water for People, Water for Life*. (1st Edition). Retrieved from http://unesdoc.unesco.org/images/0012/001295/129556e.pdf

World Health Organization. (2004). *Guidelines for drinking water quality.1* (3rd Edition) Retrieved from http://www.who.int.ezproxy1.lib.asu.edu/water_sanitation_health/dwq/gdwq0506.pdf

World Health Organization. (2004). *Water safety plan*. [guidelines for Drinking Water Quality 3rd Edition] *1*(Chapter 4) Retrieved from http://www.who.int.ezproxy1.lib.asu.edu/water_sanitation_health/dwq/gdwq3_4.pdf

Winter, T. C., Harvey, J. W., Franke, O. L. & Alley, W. M. *Ground water and surface water A single resource.* Retrieved 09/21, 2008, from http://74.125.45.104/search?sourceid=navclient&ie=UTF-8&rls=DELA,DELA:2005-51,DELA:en&q=cache:http%3A%2F%2Fpubs.usgs.gov%2Fcirc%2Fcirc1139%2Findex.html