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Analysis of Heavy Metals in Water Samples from Household Wells in Kubang Kerian

Dissertation submitted in partial fulfillment for the

Degree of Bachelor of Science in Forensics Science

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CERTIFICATE

This is to certify that the dissertation entitled

"Analysis of Heavy Metals in Water Samples from Household Wells in Kubang Kerian"

is the bonafide record of research work done by

Mr. Mohd Adib bin Yahya

During the period from December 2005 to April 2006 under my supervision

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Abbreviations:

Zn	Zinc
Cd	Cadmium
Cu	Copper
Ni	Nickel
AAS	Atomic Absorption Spectrometry
FAA	Flame Atom Atomization
GF	Graphite Furnace
TDS	Total Dissolved Solid
MPC	Maximum Permissible Concentrations
MCL	Maximum Contaminants Levels
EPA	Environmental Protection Agency

Abstract

When water becomes contaminated to the extent that is does not meet Environmental Protection Agency (EPA) drinking water quality standards, it is considered unsafe to be consumed. But if it otherwise, it means the water is safe for consumption. In this study, water samples from different well waters at seven areas were collected. In every well, the samples were taken three times; in the morning, afternoon and evening. Atomic Absorption Spectrometry (AAS) instrument was used to determine the concentration of Zn, Cd, Cu, and Ni in the samples. The pH value for all samples was also measured. Another test was Total Dissolved Solid (TDS) test. The pH values of the all samples were in the range of 6.0 to 8.5. The TDS concentrations for all samples collected at different time were between 0.021 ppm (area 4) to 0.076 ppm (area 7) in the morning, 0.026 ppm (area 4) to 0.085 (area 1) in the afternoon, and 0.013 ppm (area 4) to 0.065 ppm (area7). The concentrations of Zn for all samples collected at different time were between 0.026 ppm (area 2 and area 3) to 0.064 ppm (area 7) in the morning, 0.020 ppm (area3) to 0.063 ppm (area 7) in the afternoon, 0.025 ppm (area 2) to 0.060 ppm (area 7). The concentrations of Cd for all samples collected at different time were between 0.020 ppm (area 1) to 0.037 ppm (area 7) in the morning, 0.021 ppm (area 1) to 0.041 ppm (area 7) and 0.023 ppm (area 1) to 0.037 ppm (area 7). The concentrations of Cu for all samples collected at different time were between 0.001 ppm (area 1) to 0.017 ppm (area 7) in the morning, 0.003 ppm (area 1 and area 3) to 0.014 ppm (area 7) and 0.003 ppm (area 1) to 0.016 ppm (area 7).

The concentrations of Ni for all samples collected at different time were between 0.038 ppm (area 1) to 0.057 ppm (area 7) in the morning, 0.043 ppm (area 1) to 0.056 ppm (area 7) and 0.044 ppm (area 1) to 0.054 ppm (area 7). All the results found were compared with the standard recommended by EPA. All samples have lower concentrations as compared to EPA recommendation.

Abkstrak

Kualiti air dikatakan tercemar apabila ia tahap pencemaran yang terkandung di dalamnya melebihi tahap yang telah ditetapkan oleh "Environmental Protection Agency (EPA). Sebaliknya ia adalah selamat digunakan jika tahap pencemaran berada di bawah kategori yang ditetapkan. Dalam kajian ini, sampel air perigi dari tujuh lokasi berbeza telah diambil untuk dianalisa. Bagi setiap perigi, pensampelan dilakukan sebanyak tiga kali pada waktu yang berlainan iaitu pada waktu pagi, tengahari dan petang. Empat jenis logam berat iaitu zink, cadmium, kuprum dan nikel telah dianalisa menggunakan Atomic Absorption Spectromentry (AAS). Selain menilai tahap pH, penentuan kandungan pepejal terlarut (TDS) juga dilakukan. Kepekatan TDS bagi setiap waktu ialah di antara 0.021 ppm (lokasi 4) hingga 0.076 ppm (lokasi 7), 0.026 ppm (lokasi 4) hingga 0.085 ppm (lokasi 1), dan 0.013 ppm (lokasi 4) hingga 0.065 ppm (lokasi 7) bagi waktu pagi, tengahari dan petang. Zn menunjukkan kepekatan dari 0.026 (lokasi 2 dan 3) hingga 0.064 ppm (lokasi 7), 0.020 ppm (lokasi 3) hingga 0.063 (lokasi 7), dan 0.025 ppm (lokasi 2) hingga 0.060 ppm (lokasi 7) bagi waktu pagi, tengahari dan petang. Cd menunjukkan kepekatan dari 0.020 (lokasi 1) hingga 0.037 ppm (lokasi 7), 0.021 ppm (lokasi 1) hingga 0.041 (lokasi 7), dan 0.023 ppm (lokasi 1) hingga 0.037 ppm (lokasi 7) bagi waktu pagi, tengahari dan petang. Cu menunjukkan kepekatan dari 0.001 (lokasi 1) hingga 0.017 ppm (lokasi 7), 0.003 ppm (lokasi 1 dan 2) hingga 0.014 (lokasi 7), dan 0.003 ppm (lokasi 1) hingga 0.016 ppm (lokasi 7) bagi waktu pagi, tengahari dan petang. Ni menunjukkan kepekatan dari 0.038 (lokasi 1)

hingga 0.057 ppm (lokasi 7), 0.043 ppm (lokasi 1) hingga 0.056 (lokasi 7), dan 0.043 ppm (lokasi 3) hingga 0.054 ppm (lokasi 7) bagi waktu pagi, tengahari dan petang. Keputusan yang diperolehi dibandingkan dengan tahap yang ditetapkan oleh EPA. Kesemua sampel yang dianalisa mempunyai kepekatan yang rendah daripada kepekatan yang disyorkan oleh EPA.

Chapter 1.0: Introduction

Groundwater is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. It originates from rainfall or snow which moves through the soil into the groundwater system. Groundwater is found underground and becomes a part of hydrologic or water cycles. It begins as precipitation. Some precipitation (rain or snow) runs off into lakes, streams, rivers and wetlands. Some are evaporating back to atmosphere.

Groundwater moves through the openings that exist between soil or rock particles or along fractures. A layer of rock or soil which has capable of storing, transmitting and yielding to well is called aquifer. Aquifer is where groundwater is stored underground. Aquifer is also an underground water saturated stratum of formation that can yield usable amounts of water to well. Based on physical characteristics, there are two types of aquifers: if the saturated zone is sandwiched between layers of impermeable material and the groundwater is unfed pressure, it is called a confined aquifer; if there is no impermeable layer immediately above the saturated zone, it is called unconfined aquifer. The water surface below which water fills all the openings in soil and rock is called water table. The water table is lying between the unsaturated zone and saturated zone (figure 1). Groundwater is important to an ecosystem because it percolates into drinking water wells and water bodies, which it has capable to contaminates the water with excessive nutrients.

Groundwater is actually a valuable resource in many countries and becomes a vital source of drinking water. Under most conditions, groundwater is safer as compared to surface water because surface is more readily exposed to any pollutant that can come from the surrounding atmosphere. But, it does not mean groundwater is invulnerable to be contaminated. Contaminates still can reach wells and therefore household. Well water can be contaminated in one of two ways:

1) The aquifer from which the well draws is contaminated, or
2) Contaminated surface water enters the well.

Consequently, well type, well age, and well depth are becoming important factors in water quality. Well age is related to well type and well depth. Older wells usually tend to be shallow, dug or bored wells whereas the newer wells tend to be deep and drilled wells.

There are some factors that can cause contaminations to the groundwater;

1) Wellhead or aquifer contamination,
2) Aquifer,
3) Wells.

Due to percolation through the upper soil mantle, groundwater is considered as a safe source of water. It is because, the percolation can help soil to adsorb, filter out and degrade the contaminations. However, it is possible that wells providing direct conduit to the groundwater are contributing to the pollution or contamination of groundwater. Groundwater storage and movement is depends on the porosity of the aquifer. When the groundwater moves at slower rate, long-term effects can occur and contaminated groundwater can be undetected for years or even decades. An aquifer should have high storage capacity, high specific yield, high hydraulic capacity, and good water quality. High permeability makes the groundwater easily to be contaminated. Contaminated surface water also can cause aquifer to be contaminated. Well water quality problem often due to construction deficiencies, improper site selection, and/or the presence of fractured, channeled, and cavernous formations. Some factors that can cause well contaminations are; insufficient and substandard well casing, inadequate sealing, lack of sanitary cover, and poor welding of joints.

Water quality refers to its temperature, the amount of dissolved solids, and the presence of toxic and biological pollutants in it. High amount of dissolved material through the action of chemical weathering can have a bitter taste, and referred to as hard water. Hard water can cause the formation of scaly deposits in water heater and pipes, and makes soap difficult to lather. Groundwater quality can be adversely affected as a result of human activities that introduce contaminants into the environment. Besides, it is also be affected by natural process that result in elevated concentrations of certain constituents in the groundwater. For example, elevated metal concentrations can occur when metals are leach into the groundwater from mineral that present in the earth. The potential for a contaminant to affect groundwater quality depends on its ability to migrate through the overlying soils to the underlying ground water resource.

Most important potential source of groundwater contaminations are fuel storage practices, waste disposal practices, agricultural practices and industrial practices. Fuel storage practices include the storage of petroleum products in underground and aboveground storage tanks. Storage tanks are usually used to hold petroleum products such as gasoline and diesel fuel. If leakage occurred it can significantly cause the groundwater contaminations. The primary causes of tank leakages are faulty installation or corrosion of tanks and pipelines. Waste disposal practices include septic systems, landfills, waste piles, waste tailings, land application, unpermitted disposal and deep and shallow injection wells. Improperly constructed and poorly maintained septic systems cause nutrients and microbial contaminations to groundwater. Agricultural practices that can cause groundwater contaminations are include animal feedlots, irrigation practices, fertilizer and pesticides applications, drainage well and agricultural chemical facilities. Common mixtures of pesticides and fertilizers can have biological effects to the groundwater. For industrial process, the most common contaminations are metals, volatile organic compounds, semivolatile compounds and petroleum compounds. Metals may be present in industrial process and tend to be persistent with little to no potential to be degraded. Predicting their mobility and toxicity is complex because there is large number of chemical reactions that may affect their behavior.

There are three types of wells; dug well, driven-point and drilled well. A dug well has a large diameter-hole which usually more than 2 feet wide and often constructed by hand. It is usually shallow and poorly protected from runoff of surface water. Driven-point well is usually constructed by driving lengths of pipe into the ground. This well can be installed only in areas with loose soils such as sand. This type of well has moderate risk of contamination. Drilled well is typically the least likely to be contaminated. Well location also plays an important role in influencing the contamination. If a well is located downhill from a septic system, animal feeding lot, or over fertilized farm field, it has greater risk of contamination than a well which located uphill from these pollution sources. Well age is also can affect the contamination in which older well usually has a greater risk to be contaminated.

Basically, contamination of groundwater can result in poor drinking quality, loss of water supply, degraded water system, high cleanup cost, high cost for alternatives supplies and/or potential health problems. So, it is our responsibilities to protect our groundwater from being contaminated.

Porosity and permeability

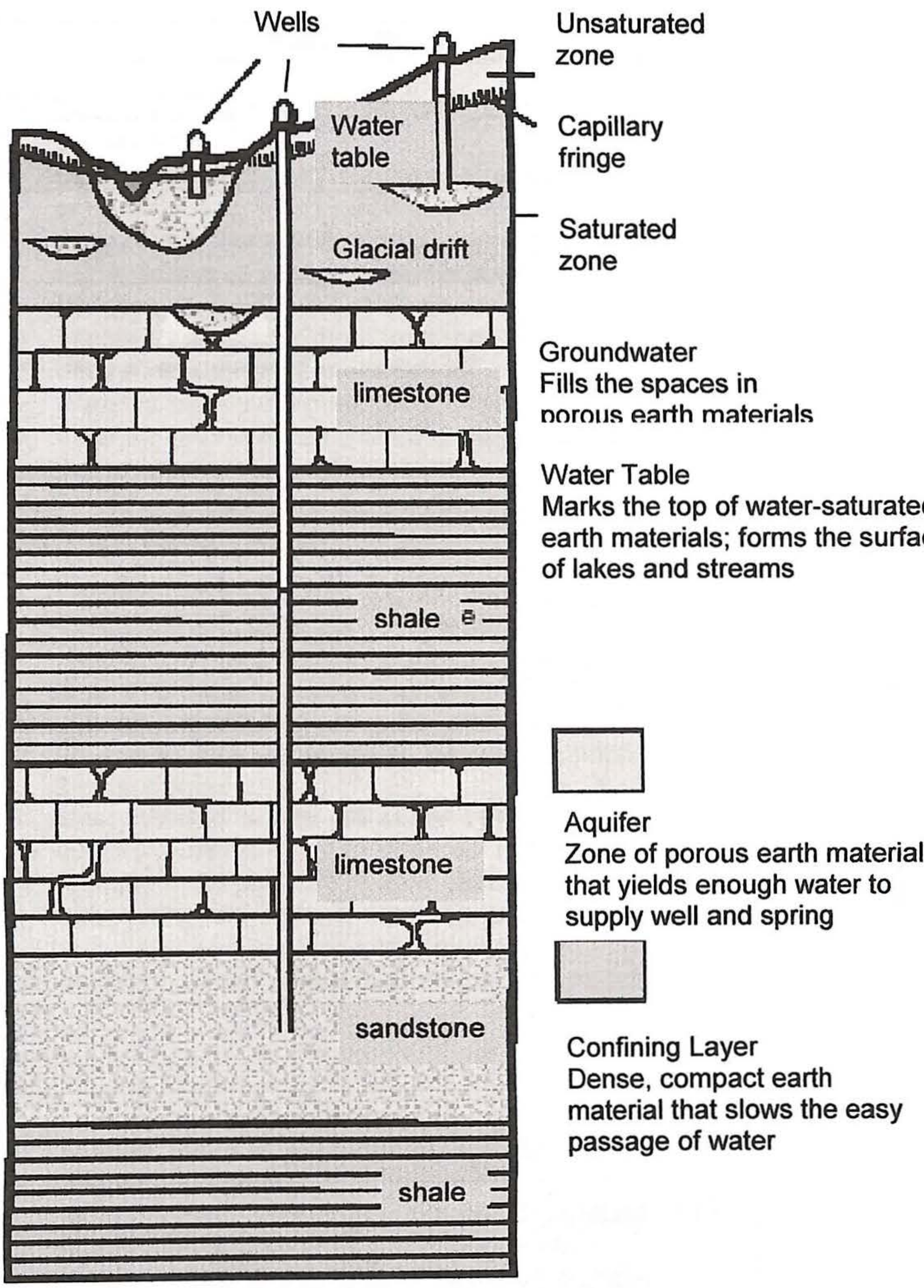

Figure1: Basic of Groundwater (Iowa's Groundwater Basic)

Table 1: Some Contaminants in Groundwater (www.cdc.gov/ncidod/healthywater)

Microorganisms	Health Effects
Bacteria	
Campylobacter	• Diarrhea (sometime bloody), cramping, abdominal pain, and fever
Escherichia (E. coli) 0157:H&	• Bloody or non-bloody diarrhea, stomach cramps; little or no fever • Can cause hemolytic, uremic syndrome (HUS) and kidney failure in young children or the elderly
Salmonella	• Diarrhea, typhoid fever, stomach cramps • Infection can spread from intestines to blood and other body sites, causing serious illness
Shigella	• Water or bloody diarrhea, fever, upset stomach • Vomiting and stomach cramping may occur
Viruses	
Enterovirus	• Usually causes mild upper respiratory, "flu-like" symptoms with fever and muscle pains, or a rash • Meningitis is less common, and illnesses that affect the heart and brain may occur, but are very rare
Hepatitis A	• Jaundice (yellowing of eyes and skin), dark urine, tiredness, loss of appetite, nausea, vomiting, fever, stomach ache • Most infected adults will show symptoms while show symptoms while children often do not have symptoms (but could still pass the virus to others)
Norovirus (Norwalk)	• Upset stomach, cramps, vomiting, and diarrhea • Headache and low grade may also occur
Rotavirus	• Vomiting, watery diarrhea, stomach cramps, fever
Protozoa	
Cryptospiridum	• Diarrhea, loose or watery stool, stomach cramps, upset stomach, and fever • Usually causes mild illness, but can be serious or fatal for people with weakened immune systems
Giardia	• Diarrhea, loose or watery stool, stomach cramps • Usually causes mild illness, but can be serious or fatal for people with weakened immune systems

Continued

Chemicals	Health Effects
Atrazine	• Short-term: congestion of heart, lungs, and kidney; low blood pressure; muscle spasms; weight loss; damage to adrenal glands • Long-term: weight loss, cardiovascular damage, eye and muscle degeneration; cancer
Arsenic	• Stomach pain, nausea, vomiting, diarrhea, numbness in hands and feet, partial paralysis, and blindness • Can also cause skin damage, circulatory system problems, and increased risk of cancer
Copper	• An essential nutrient at very low levels • High level exposure causes upset stomach, vomiting, diarrhea, and stomach cramps
Lead	• Delayed physical and mental development in babies • Shortened attention span, hearing, and learning abilities of children • Slightly increased blood pressure in adults • Long-term exposure at high levels can include stroke, kidney disease, and cancer
Mercury	• Kidney damage
Nitrate	• Methemoglobinemia-a blood disorder that causes shortness of breath and blueness of skin, and can lead to serious illness or death • Long-term effects include increased urination and bleeding of the spleen
Radium	• Increases risk of cancer
Volatile Organic Compounds (VOCs)	• Drowsiness and decreased responsiveness • Skin irritation • Some cause cancer after long term exposure

(www.cdc.gov/ncidod/healthywater)

Chapter 2.0: Literature Review

2.1: The importance of groundwater

Groundwater is a crucial global which provide relatively cheap and reliable water supply for both rural and urban area. Groundwater also supplies as many as 2 billion people with drinking water, and it is found that 40% of world's food is produced by irrigated agriculture which relies on groundwater. Groundwater is extremely important both for drinking water and its natural systems (Loe, 2005). Industry and agricultures also utilize significant quantities of groundwater for processing and irrigation (Angle et al., 2003). In the developing world, one person in three is lacks of safe drinking water and sanitation (Palamuleni, 2002).

Depending on the depth of the groundwater, the quality of drinking water and chance of being polluted-varies from place to place. The deeper the well usually shows the better the groundwater quality. The amount of new water flowing into the area can also affect its quality (USEPA, 2002). Ground water is actually vulnerable (Weighman & Kroehler, 1990), although often unhealthily regarded as "out of sight, out of mind" (IEN, 1992). Groundwater contamination can result in poor drinking water quality, loss of a water supply, and/or potential health problems (USEPA, 1993).

Unlike other natural sources or raw materials, groundwater is present throughout the world. Groundwater is also related to atmospheric or climatic process, to the surface water regimes of rivers and lakes, and with the springs and wetlands where it naturally discharges onto the surface of the ground (planet earth, 2005).

An individual concerned about his/her water supply is recommended to investigate further if any of these cases apply: (Whitsell & Hutchinson, 1973).

1) Persistent illness of user(s)

2) Open well, spring or cistern

3) Turbid water after rainstorm

4) Dug well with jointed casing

5) Well or spring located in an area subject to flooding

6) Area of sinkhole, cavernous, or fractured rock geology or

7) Crowded residential area or industrial development without community sewage facilities

It is difficult to detect the contamination until the water is brought to the surface. In fact, the most common contaminants occur in small amounts and are odorless and colorless (Weigman & Kroehler, 1990).

Groundwater resources are threatened by overuse and contamination for both developed and developing country around the world. From human viewpoint, groundwater contamination becomes a problem when aquifers supplying wells that used for drinking water become contaminated (Loe, 2005). The characteristics of the aquifer systems can contribute for the contaminations of the groundwater (Angle et al., 2003). Both human activities and natural sources can cause the contamination of groundwater (USEPA 1993, Hallberg 1989, Powell et al., 1990).

Human activities are found to having long term, negative effects on groundwater (Weigman & Kroehler, 1990). Pollutants such as bacteria and nitrates, Concentrated Animal Feeding Operation (CAFOs), heavy metals, fertilizers and pesticides, industrial product and wastes, household wastes and Lead and Copper are recognized in causing pollution that result from human activities whereas natural sources that can contaminate groundwater can come from microorganism, radionuclides, nitrates and nitrites, heavy metals and fluoride (USEPA 2002). Well water pollution can make us become sick. Once a well is polluted cleaning it up is difficult and costly (Hawaii's Pollution Prevention Services, 2000). Various mapping strategies are useful for identifying for vulnerable aquifers. The mapping programs can identifies areas that are vulnerable to contamination and can assist in groundwater protection strategies (Angle et al., 2003).

Six steps are recommended for the protections of well water; (USEPA, 2002).

1) Identify potential problem sources,
2) Discuss with "local expert",
3) Have water test periodically,
4) Have the test result interpreted and explained clearly,
5) Set a regular maintenance schedule, do the scheduled maintenance and keep accurate and up-to-date records,
6) Remedy any problems

Provision for safe drinking water needs "multi barrier" approaches that direct attention both to water supply systems and to water source area. In the context of water supply system, it requires appropriate standards, operating procedures and technologies (Loe, 2005).

Angel et al., 2003 reported DRASTIC as a mapping system that allows the pollution potential of any area to be evaluated systemically using existing information. It evaluates the pollution potential of an area under the assumption that a contaminant with the mobility of water is introduced at the surface and flushed into the groundwater by precipitation. There are seven factors that contribute to DRASTIC methodology and are the basis for the name. They are;

1) Depth to water
2) Recharge
3) Aquifer media
4) Soils
5) Topography
6) Impact of vadose zones and
7) Hydraulic Conductivity

2.2: Research Objectives

1) To determine the concentration of heavy metals (Ni, Zn, Cu, and Cd) in household well water in areas in Kubang Kerian, Kelantan.
2) To find out whether there are significant different between the concentrations of heavy metals in the household well water sampled in the morning, afternoon and evening.
3) To determine whether the level of heavy metals, pH and total dissolved solid in the household well water are safe for consumption.