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Physiochemical Quality of the Water Sources in Shendi Locality, River Nile state Sudan

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ABSTRACT

This observational, cross-sectional research was designed as community based cross-sectional study in the locality of Shendi, to assess the quality of drinking water and its health risk and impact and consequences to consumers. The study involved all the towns and the villages, the population, and their drinking water sources. System of proportional stratified sampling allocation was followed to select the sample from the water source and the community. Interview, Sanitary and medical surveys and Experimental field and laboratory works for chemical analysis of drinking water sources, was followed for data collection. A highly significant difference was found between the mean levels of turbidity and other physical and chemical parameters. The mean concentration of chloride as *cl* mg/l was found to be highly associated with ground sources. The electrical properties observable in deep groundwater can be related to the concentration of ions and mineral salts as shown above and carbon dioxide dissolved in it. Both Nitrite as NO_2 and Nitrate as NO_3 found to be highest in the shallow wells. Highly significant difference of fluoride means was observed among the various types of drinking water sources. Subsurface shallow water, count the highest level of total dissolved solid (TDS) mg/l. The mean level of hardness mg/l was found high in the ground water. It was observed that the people, who were consuming water of high physical and chemical level in Shendi locality, were suffering more than others from infectious and chronic diseases. Based on the results discussion and conclusion of this study the following recommendations are proposed to help in an improvement sources of drinking water management and which likely to involve consumers in preparing and using safe water at the household level, which will facilitate the ultimate goal of providing all of the Shendi's population with community piped water that is accessible, safe and affordable

Keywords: Water, Water quality, Drinking water.

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INTRODUCTION

Water has a profound influence on human health. At a very level, a minimum amount of water is required for consumption on a daily basis for survival and therefore access to some form of water has much broader influence on health and well being and issues such as the quantity and quality of the water supplied are important in determining the health of individuals and whole communities (1).

Since 1990 well over 2 billion people have gained access to improved sources of drinking water, and 116 countries have met the MDG target for water. More than half the world's population almost 4 billion people, now enjoy the highest level of water access: a piped water connection at their homes. But much remains to be done. More than 700 million people still lack ready access to improved sources of drinking water; nearly half are in sub-Saharan Africa. More than one third of the global population – some 2.5 billion people — do not use an improved sanitation facility, and of these 1 billion people still practice open defecation. (2)

The first priority must be to provide access for the whole population to some form of improved water supply. However, access may be restricted by low coverage, poor continuity, insufficient quantity, poor quality and excessive cost relative to the ability and willingness to pay. Thus, in terms of drinking water, all these issue must be addressed if public health is to improve.

The quality of water does, however, have a great influence on public health; in particular the microbiological quality of water is important in preventing ill-health. Poor microbiological quality is likely to lead to outbreaks of infections water related diseases and might causes serious epidemics to occur.

Physicochemical parameter of any water body plays a very important role in maintaining the fragile ecosystem that maintains various life forms (3). Chemical water quality is generally of water importance as the impact on health tends to be chronic long term effects and time is available to take remedial action. Acute effects may be encountered where major pollution event has occurred or where levels of certain chemical are high from natural sources, such as fluoride, or anthropogenic sources, such as nitrate (1).

The guidelines for drinking water quality recommended by WHO (1993 and 1996) relate to following variables:

Acceptability aspects (Physical parameters):

The ordinary consumer judges the water quality by its physical characteristics. The provision of drinking water that is not only safe but also pleasing in appearance, taste and a dour is a matter of

high priority. The supply of water that is unsatisfactory in this respect will undermine the confidence of consumers, leading to use of water from less safe source. The acceptability of drinking-water can be influenced by many different constituent (4 & 5). These are:

1 Turbidity:

Turbidity is a cloudiness or haziness of water (or other fluid) caused by individual particles (suspended solids) that are generally invisible to the naked eye, thus being much like smoke in air. Turbidity in drinking water is caused by particulate matter that may be present as a consequence of inadequate treatment or from re-suspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some ground water (6). Measurement of turbidity is a key test of water quality. The higher the turbidity, the higher the risks of the drinkers developing gastrointestinal diseases, especially for immune-compromised people, because contaminants like virus cause the particles act as shields for the virus and bacteria. Viruses or bacteria can become attached to the suspended solid; the suspended solid interfere with water disinfection with chlorine be water turbidity is the leading cause of gastrointestinal cancer in the United States(7) Turbidity measured this way uses an instrument called a nephelometer with the detector setup to the side of the light beam. More light reaches the detector if there are lots of small particles scattering the source beam than if there are few. The units of turbidity from a calibrated nephelometer are called Nephelometric Turbidity Units (NTU). Turbidity interferes with disinfections and microbiological determination –water with turbidity of less than 5 nephelometric turbidity units (NTU) is usually acceptable to consumer.

There are frequently standards on the allowable turbidity in drinking water. In Sudan as SSMO, March (2002) the maximum allowable standard is 5NTU. In the United States (as of 2003) the allowable standard is 1 NTU, with many drinking water utilities striving to achieve levels as low as 0.1 NTU (4 & 5).

2 Colour:

The color of a water sample can be reported as:

- Apparent color
- True color

Apparent color is the color of the whole water sample, and consists of color due to both dissolved and suspended components.

True color is measured by filtering the water sample to remove all suspended material, and measuring the color of the filtered water, which represents color due to dissolved components.

Testing for color can be a quick and easy test which often reflects the amount of organic material in the water (although certain inorganic components like iron or manganese can also impart color) (8) & (9).

Drinking water should be free from colour which may be due to the presence of colored organic matter (primarily humic substances), metals such as iron and manganese, or highly colored industrial wastes. Consumers may turn to alternative, perhaps unsafe, sources when their water is colored to an aesthetically displeasing degree. The guide line value is up to 15 true colour units (TCU) although levels of colour above 15 TCU can be detected in a glass of water(4 & 5).

3 Taste and odour:

Taste and odour originate from natural and biological sources or processes, from contamination by chemicals, or as a by product of water treatment (e.g. chlorination). No health – based guideline value is proposed for taste and odour(4 & 5).

4 Temperature:

Cool water is generally more palatable (pleasing to the taste). Low water temperature tends to decrease the efficiency of treatment process, including disinfection, and may thus have a deleterious effect on drinking water quality. However, high water temperature enhances the growth of microorganisms and taste, odour, colour and corrosion problem may increase. No guideline value is recommended since its control is usually impracticable.

To sum up, we cannot judge the quality of drinking water by physical characteristics alone. A detailed chemical and microbiological examination is also needed for complete assessment(4 & 5).

5 Electrical conductivity:

A common misconception about water is that it is a good conductor of electricity, with risks of electrocution explaining this popular belief. Any electrical properties observable in water are from the ions of mineral salts and carbon dioxide dissolved in it. Water does self-ionize where two water molecules become one hydroxide anion and one hydronium cation, but not enough to carry enough electric current to do any work or harm for most operations. In pure water, sensitive equipment can detect a very slight electrical conductivity of (0.055 μ S/cm at 25°C). Pure water can also be electrolyzed into oxygen and hydrogen gases but in the absence of dissolved ions this is a very slow process and thus very little current is conducted.

Water can dissolve many different substances imparting upon it different tastes and odors. In fact, humans and other animals have developed senses to be able to evaluate the drink ability of water: animals generally dislike the taste of salty sea water and the putrid swamps and favor the purer water of a mountain spring or aquifer. The taste advertised in spring water or mineral water derives from

the minerals dissolved, while pure H₂O is tasteless. As such, purity in spring and mineral water refers to purity from toxins, pollutants, and microbes (7,8 &9).

Chemical aspects

Chemical contamination of drinking – water may also have effects on health, although in general these tend to be chronic rather than acute, unless a specific pollution event has occurred and therefore generally considered of lower priority than microbiological contamination.

Chemical pollutants which affect health include nitrate, arsenic, mercury and fluoride, however, it must be recognized that increased concentrations of any chemical known to have an impact on human health may lead to long-term problems. In general, water sources used for drinking-water supply should be protected from chemical contamination through land-use control, definition of protection zone and application of adequate waste water treatment (10).

There are few chemical constituents of water that can lead to acute health problems through massive accidental contamination of a supply. Moreover, experience shows that, in such incidents the water usually becomes undrinkable owing to unacceptable taste, odor and appearance.

The problem associated with chemical constituents of drinking – water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure; of particular concern are contaminants that have cumulative toxic properties , such as heavy metals and substances that are carcinogenic.

Health – related chemical constituents:

The presence of certain chemicals in excess of prescribed limits may constitute ground for rejection of the water as a source of public water supply. These substances may be inorganic or organic.

Inorganic Constituents:

These substances include arsenic, cadmium, chromium, cyanide, fluoride, lead, mercury, nickel, nitrate, selenium etc.

The guide line values of inorganic chemicals of health significance in drinking water are shown in the below table:

Constituents	Recommended maximum limit of concentration (mg/litre)
Antimony	0.005 (P)
Arsenic	0.01 (P)
Barium	0.7
Boron	0.3
Cadmium	0.003
Chromium	0.05 (P)
Copper	2 (P)
Cyanide	0.07

Fluoride	1.5
Lead	0.01
Manganese	0.5 (P)
Mercury (Total)	0.001
Molybdenum	0.07
Nickel	0.02
Nitrate as (NO ₃)	50
Nitrate as (NO ₂)	3 (P)
Selenium	0.01

P = Provisional guide line value (GV)

1 Arsenic: A provisional GV of 0.1mg/L has been set for arsenic on the basis of an excess cancer risk of 6×10^{-4} . In some parts of the world, natural sources of arsenic may contaminate water supplies and lead to poisoning of the users. Common symptoms include inflamed eyes and skin lesions.

Most natural arsenic comes from the reduction of arsenic complexes caused through changing redox and pH conditions and from the oxidation of arsenic containing minerals exposed by falling ground water tables induced through over abstraction or reduced recharge.

There is also increasing evidence that there is a tendency for arsenic level to increase in shallow groundwater under urban areas (10). Arsenic is introduced into water through the dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition; concentrations in ground water in some areas are sometimes elevated as a result of erosion from natural sources (8 & 6).

2 Cadmium: metal is used in the steel industry and in plastics, cadmium compounds are widely used in batteries. Pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking water may also be caused by impurities in the zinc of galvanized pipes and some metal fittings, although levels in drinking water are usually less than 1 Mg/litre. Absorption of cadmium compound is dependent on the solubility of the compound. Cadmium accumulates primarily in the kidneys and has a long biological half life in humans of 10 – 35 years (6).

3 Chromium: Chromium is widely distributed in the earth's crust. In general, food appears to be the major source of intake. The absorption of chromium after oral exposure is relatively low and depends on the oxidation state (4, 5 & 6).

4 Cyanide: The acute toxicity of cyanide is high. Cyanides usually found in drinking water, primarily as a consequence of industrial contamination. Effects on thyroid and particularly the nervous system were observed in some populations as a consequence of the long – term consumption of adequately processed cassava containing high levels of cyanide (6).

5 Fluoride: Fluoride in drinking – water can have toxic effects in both excess and deficiency, although WHO only set a GV of 1.5mg/L for excess fluoride as susceptibility in deficiency is highly dependent on nutritional status.

Excess fluoride may lead to dental or skeletal fluorosis , the latter being a crippling disease which affects number of area including the Rift valley of East Africa and parts of India, Mexico and the former Soviet Union. However, a lack of fluoride may cause dental caries, a weakening of the teeth, thus in some circumstances fluoride may be added to the drinking – water supply.

The acceptable concentration of fluoride in water is in part related to climate, as in warmer climates the quantities of water consumed are higher thus leading to a greater risk of fluoride related problems as overall intake increases. Susceptibility of individuals to fluorosis may also be determined by renal impairment (6&10).Fluoride accounts for about 0.3g/kg of the earth’s crust. Inorganic fluorine compounds are used in the production of aluminium, and fluoride is released during the manufacture and use of phosphate fertilizers which contain up to 4 percent fluorine. Additional intake may result from the use of fluoride toothpastes.

Exposure to fluoride from drinking water depends greatly on natural circumstances. Levels in raw water are normally below 1.5 mg/litre, but ground water may contain about 10mg/litre in areas rich in fluoride- containing minerals. Such high levels have at times led to dental or skeletal fluorosis. Fluoride is sometimes added to drinking water to prevent dental caries

6 Lead: Lead is present in tap water to some extent as a result of its dissolution from natural sources, but primarily from household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, and water hardness and standing time of the water, with soft, acidic water being the most plumb solvent (6).

7 Nitrate: Nitrate can reach high levels that can potentially cause the death of fish. While nitrate is much less toxic than ammonia or nitrite, levels over 30 ppm of nitrate can inhibit growth, impair the immune system and cause stress in some aquatic species. In most cases of excess nitrate concentrations, the principal pathway of entering aquatic systems is through surface runoff from agricultural or landscaped areas which have received excess nitrate fertilizer. These levels of nitrate can also lead to algae blooms, and when nutrients become limiting (such as potassium, phosphate or nitrate) then eutrophication can occur. As well as leading to water anoxia, these blooms may cause other changes to ecosystem function, favouring some groups of organisms over others. Consequently, as nitrates form a component of total dissolved solids, they are widely used as an indicator of water quality(11) & (12).

Excess nitrate in drinking-water has been linked to methaema globin anemia in infants, (blue- baby' syndrome). Nitrate leads to the oxidation of normal hemoglobin to methaemo globin which is unable to transport oxygen to the tissues.

The Guideline Value (GV) for nitrate of 50mg/L has been set on the basis of the acute health risk to infants and is unusual for this reason as most GVs are set for long-term risks. Many countries are now experiencing problems with elevated (10).

8 Chlorides: All waters including rain water contain chlorides. The standard prescribed for chloride is 200 mg/ litre. The maximum permissible level is 600 mg/litre (4& 5,10).

9 Hardness: Water hardness is also a critical factor in food processing. It can dramatically affect the quality of a product as well as playing a role in sanitation. Water hardness is classified based on the amounts of removable calcium carbonate salt it contains per gallon. Water hardness is measured in grains; 0.064 g calcium carbonate is equivalent to one grain of hardness (13). Water is classified as soft if it contains 1 to 4 grains, medium if it contains 5 to 10 grains and hard if it contains 11 to 20 grains (14) The hardness of water may be altered or treated by using a chemical ion exchange system. The hardness of water also affects its pH balance which plays a critical role in food processing. For example, hard water prevents successful production of clear beverages. Water hardness also affects sanitation; with increasing hardness, there is a loss of effectiveness for its use as a sanitizer

The taste threshold for calcium ion is in the range of 100-300 mg/litre, depending on the associated anion, and the taste threshold of magnesium is probably less than for calcium. In some instances water hardness in excess of 500 mg/litre is tolerated by consumers.

Depending on the interaction of other factors, such as pH and alkalinity, water with a hardness of approximately 200mg/litre may cause scale deposition in the distribution system and will result in excessive soap consumption and subsequent scum formation. On heating, hard water forms deposits of calcium carbonate scale. Soft water, with a hardness of less than 100mg/litre, may, on the other hand, have a low buffer capacity and so be more corrosive for water pipes.

10 Ammonia: The ammonia includes the non-ionized (NH₃) and ionized (NH₄⁺). Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfections with chloramines. Natural levels in ground and surface waters are usually below 0.2mg/litre. Anaerobic ground waters may contain up to 3 mg/litre. Intensive rearing of farm animals can give rise to much higher levels in surface water. Ammonia contamination can also arise from cement mortar pipe linings. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution, Ammonia can compromise disinfection efficiency, result in nitrite formation in

distribution systems, can cause the failure of fillers for the removal of manganese, and cause taste and odour problems (6).

11 pH: The concept was introduced by S.P.L. Sorensen in 1909, and is purported to mean pondus hydrogenii in Latin (winkipedia.org/wik Phapril 19,2006) However, most other sources attribute the name to the French term pouvoir hydrogène. In English, pH can stand for "hydrogen power, power of hydrogen "or "potential of hydrogen(13).

One of the main objectives in controlling the pH is to minimize corrosion and incrustation in the distribution system. pH levels of less than 7 may cause severe corrosion of metals in the distribution pipes and elevated levels of certain chemical substances, such as lead, may result. At pH levels above 8 there is a progressive decrease in the efficiency of the chlorine disinfection process. An acceptable pH drinking water is between 6.5 and 8.5. In the absence of a distribution system, the acceptable range of pH may be broader(6).

12: Hydrogen sulfide: The taste and odour threshold of hydrogen sulfide in water are estimated to be between 0.05 and 0.1mg/litre. The "rotten eggs" odour of hydrogen is particularly noticeable in some ground waters and in stagnant drinking water in the distribution system, as a result of oxygen depletion and the subsequent reduction of sulfate by bacterial activity. Sulfide is oxidized rapidly to sulfate in well-aerated water and hydrogen sulfide levels in oxygenated water supplies are normally very low (4, 5 & 6).

13: Iron: Anaerobic ground water may contain ferrous iron at concentration of up to several mg/litre without discoloration or turbidity in water when directly pumped from the well. On exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish – brown colour to the water iron also promotes the growth of "iron bacteria", which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the pipe. At level 0.3 mg/litre, iron stains laundry and plumbing fixtures.

14 Sodium: The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200 mg/litre.

15 Sulfate: The presence of sulfate in drinking water can cause noticeable taste. It is generally considered that taste impairment is minimal at levels below 250 mg/litre. It has been found that addition of calcium and magnesium sulfate (but not sodium sulfate) to distilled water improves the taste; optimal taste was recorded at 270 and 90 mg/litre for the two compounds respectively.

16 Total dissolved solids (TDS): TDS can have an important effect on the taste of drinking water. The palatability of water with a TDS level of less than 600 mg/litre is generally considered to be

good. Drinking water becomes increasingly unpalatable at TDS levels greater than 1200 mg/litre. Water with extremely low concentration of TDS may be unacceptable because of its flat, insipid taste. The presence of high level of TDS may also be objectionable to consumers owing to excessive scaling in water pipes, heaters, and boiler and household appliances. Water with concentrations of TDS below 1000mg/litre is usually acceptable to the consumers.

17 Zinc: Zinc imparts an undesirable astringent taste to water containing zinc at concentrations in excess of 5 mg/litre may appear opalescent and develop a greasy film on boiling, although these effects may also be noticeable at concentrations as low as 3mg/liter.

18 Manganese: Manganese concentrations below 0.1mg/litre are usually acceptable to consumers; this may vary with local circumstances. At levels above 0.1mg/litre, manganese in water supplies stains sanitary ware and laundry, and causes an undesirable taste in beverages. It may lead to accumulation of deposits in the distribution system. Even at concentration of 0.02 mg/litre, manganese, will often form a coating on pipes, which may slough off as a black precipitate.

19 Dissolved oxygen: The dissolved oxygen content of water is influenced by the raw water temperature, composition, treatment and any chemical or biological processes taking place in the distribution system.

Depletion of dissolved oxygen in water supplies can encourage microbial reduction nitrate to nitrite and sulfate to sulfide, giving rise to odour problem. It can also cause an increase in the concentration of ferrous iron in solution. No health – based guideline value has been recommended.

20 Copper: The presence of copper in a water supply in increases the corrosion of galvanized iron and steel fillings. Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/litre.

21 Aluminum: The presence of aluminum at concentrations in excess of 0.2 mg/litre often leads to deposition of aluminum hydroxide flock in distribution system and the exacerbation of discoloration of water by iron (6&16).

Chemical contamination:

A significant number of very serious problems may occur as a result of the chemical contamination of water resources.

Some potentially chronic effects may occur in rural areas where over use of agrochemicals lead to significant levels of pesticides in water sources. The presence of nitrate and nitrite in water may result from the excessive application of fertilizers or from leaching of wastewater or other organic waste into surface water and ground water (17).

In areas with aggressive or acidic waters, the use of lead pipes and fittings or solder can result in elevated lead mottling of teeth and (in severe cases) skeletal fluorosis and crippling. Similarly, arsenic may occur naturally, and long – term exposure via drinking water may result in a risk to health (18). Drinking water must contain less than the following minimum quantities of chemical impurities: lead, 0.1ppm; fluorine, 1.5ppm; arsenic and selenium, 0.05ppm; copper, 0.3ppm; iron and manganese, 0.3ppm; magnesium, 125ppm; zinc, 15ppm; chloride and sulfate, 250ppm; total solids, 500ppm; phenol, 0.001ppm (19).

Radiological aspects:

Guideline values recommended take account of both naturally occurring radioactivity and any radioactivity that may reach the water source as a result of man's activities. From a radiological point of view, they represent a value below which water can be considered potable without any further radiological examination.

The activity of a radioactive material is the number of nuclear disintegration per unit of time. The unit of activity is a bequerel (Bq); 1Bq = 1disintegration per second. Formerly, the unit of activity was curi (Ci).

The proposed guideline values are:

Gross alpha activity 0.1 Bq/L

Gross beta activity 1.0 Bq/L (6)

The initiating event in the process of chemical carcinogenesis is the induction of a mutation in the genetic material (DNA) of somatic cells. There are, however, carcinogens that are capable of producing tumors without genotoxic activity, but through an indirect mechanism. It is generally believed that a threshold dose exists for these non-genotoxic carcinogens (20).

MATERIALS AND METHOD

Type and area of the study:

This observational, cross-sectional research was designed as community based cross-sectional study in the locality of Shendi, to assess the quality of drinking water and its health risk and impact and consequences to consumers (i.e., what can happen and how) should be identified and documented for each component of the drinking-water system, regardless of whether or not the component is under the direct control of the drinking-water supplier. To identify all possible hazards associated with drinking-water and hazard would have an adverse public health consequence, as well as the identification pathways from source(s) to consumer(s).

The sources for drinking water in the locality are various for these villages. There are about 54 artesian wells 29 of which are at the north of the locality, with mean depth about 140 – 1001m and average productivity of 216 to 8000 gallons per hour for each one. And 25 of these boreholes at northern of the locality, with mean depth about 99 – 540 and average productivity of about 880 to 9600 gallons per hour for each borehole. 28 Nile stations proposed to have slow sand filters but all of these Nile stations are without filter beds .The average productivity for each station is about 65 to 100 cubic meters/ hour. There are 16 hand pump wells 13 of these types are at northern and 6 at southern of the Shendi locality. 10 Hafirs supply water all over the year, with average productivity of about 30000 cubic meters / hour for each Hafir, and a lot numbers of rain season traditional Hafirs, and a lot numbers of shallow wells with various depth few of them still in use. These shallow wells were closed by the governorate authorities which, declared them as not suitable and prohibited to use for human consumption because all of these sources lack hygienic precautions and may be exposed to contamination from man and animals excreta. Also there is only one reservoir constructed on El Awataib valley in 2004.

Study population and sampling technique:

The study involved all the towns and the villages, the population, and their drinking water sources, distribution vessels & storages utensils of drinking water in the locality of Shendi.

Sampling technique:

System of proportional stratified sampling allocation was followed to select the sample from the water source and the community. Each water source considered as separate stratum and therefore we have four strata (Hafir, Borehole, Nile station and Hand pump wells) the required sample size was determined using the formula:

$$n = \{ 2\sigma^2 (Z_{\theta} + Z_p)^2 \} / d^2$$

Where $\sigma = 7.14$

Z_{θ} = the value of standard normal variable corresponding to 95% confidence level = 1.96

Z_p = is the false negative probability = 1.282

d = is the smallest difference we wish to detect = 4.8

Sample of size {45} was appointed accordingly.

The following table shows the strata and corresponding sample size of the sources:

Source	Number	Sample size
Borehole	68	27
Nile station	28	11
Hand pump	9	3
Hafir	10	4

Total	115	45
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Sampling from the households:

The total number of household is about {250000} from which {180000} are rural population. A sample of {320} households was selected using the previous formula with $d = 1.82$, where {230} household were selected from the rural areas.

Using probability proportional to the size system the villages and blocks were listed into six strata based on their type of drinking water source mainly and considering geographical location. The proportional allocation was used to select households from strata using systematic random sampling.

Data collection:

The data of the study was directly collected from the field by:

1. In structural interview (interview using the same questionnaire) with the households heads in the community, the operators of drinking water sources and with the workers of health authority.
 - i) Sanitary and medical surveys of the households concerning drinking water handling.
 - ii) Sanitary survey for drinking water sources in Shendi locality.
2. Experimental field works chemical analysis of drinking water sources.

Chemical analysis:

Drinking water from the sources also had been analyzed using techniques for chemical testing. A selected number of physicochemical parameters were measured in order to establish whether or not the problem of chemical contaminations exists.

The water was examined for satisfactory taste, odor, and colours and for the minimum quantities of chemical impurities (WHO, guideline for water, vol.3, 1997).

Physical properties of water

3-10-1/ Appearance (estimation)

3-10-2/ Odour: (estimation)

3-10-3/ Colour: Absorbance analysis involves filtration through a cellulose-acetate membrane and subsequent spectrophotometric measurement of the absorbance of the filtrate (using spectrophotometer).

3-10-4/ ph direct reading color comparison method (relative method)

3-10-5/ Suspended solids.

Direct measurement by using (HACH) 2000 DR spectrophotometer with wavelength (810 nm).

Results are reported in mg/l suspended solids

3-10-6/ electric conductivity

Direct reading by using conductivity meter

Results are reported in $\mu\text{s}/\text{cm}$

3-10-7/ temperature direct reading

3-10-8/ Turbidity (nephelometric method).

this method depend on a comparison of the intensity of light scattered by the sample under defined condition with the intensity of light scattered by standard reference suspension under the same condition.

Method

Direct reading by using (HACH) 2100 Turbidity meter

Results are reported in (NTU)

Approval of method: Standard method (method NO 2130)

Inorganic substances:

1/hardness (total)

Dissolved minerals cause hardness in water primarily divalent cations, Calcium & Magnesium ions usually are the only ions present in significant amount there for hardness generally is considered to be a measure of the Calcium & Magnesium content of water.

Procedure:

The pH of the sample adjusted to 10 with ammonium chloride \ hydroxide solution, addition of eriochrome black T indicator followed by titration Vs (EDTA disodium salt).

Result recorded as mg/l total hardness calculated as calcium carbonate

2/Calcium

Calcium hardness determined after removing magnesium interference by adjusting the ph of the sample to 12 with sodium hydroxide, and then the amount of calcium calculated.

The results are reported as mg/l calcium.

3/ Magnesium

Magnesium determined by using mathematical method by subtracting the calcium hardness from total hardness the remained amount contributed to the magnesium
the results are reported in mg/l magnesium.

The method for total hardness, calcium & magnesium taken from (quantitative inorganic chemistry)

5/ Chloride

Sample titrated Vs standard silver nitrate solution in the presence of potassium chromate as indicator.

Result reported in mg/l chloride.

(Quantitative inorganic chemistry)

6/ Nitrate

cadmium metal reduce nitrates present in the sample to nitrite which in acidic medium react with sulfanilic acid to form an intermediate diazonium salt, this salt couples with gentistic acid to form an amber colored product the intensity of color directly proportion to the amount of nitrate

Wavelength (500) nm.

Instrument: (HACH) 2000 DR spectrophotometer.

Results are reported in mg/l nitrate

7/ Nitrite

Nitrite in the sample is react with subfamily acid to form anintermediat diazonium salt couples with chromotropic acid to form pink colored the intensity of color in proportional to the amount of nitrite in the sample.

Wavelength (A) 507 nm

Instrument: (HACH) 2000 DR spectrophotometer.

Results are reported in mg/l nitrite(EPA) approve.

8/ Ammonia

Nessler method

Nessler reagent react under strongly alkaline condition with the ammonia present in the sample to produce yellow colored species the intensity of color in proportional to the amount of ammonia in the sample.

Wavelength (425) nm. Instrument: (HACH) 2000 DR spectrophotometer. Results are reported in mg/l ammonia (EPA) approve.

9/ Sulfate

Sulfate in sample react with barium chloride to form a-precipitate of barium sulfate the amount of turbidity formed is directly in prop Oliion to the amount of sulfate.

Wavelength (450) nm.

Instrument: (HACH) 2000 DR spectrophotometer.

Result reported in mg/l sulfate

Ref/ standard method for the examination of water & waste water

10/ Fluoride

SPANDS method

This method involve the reaction of fluoride with a red zirconium - dye solution the fluoride react with part of the zirconium to form a colorless complex thus bleaching the red color in amount

proportional to the concentration of fluoride in the sample.

Wavelength (580) nm.

Instrument: (HACH) 2000 DR spectrophotometer.

Result reported in mg/l fluoride

Ref/ standard method for the examination of water & waste water

11/ Iron ferrous

1, 10 phenanthroline method:

1, 10 phenanthroline react with ferrous to form an orange color the intensity of color is proportional to the amount of ferrous in the sample Wavelength (510) nm.

Result is reported in mg/l ferrous iron

Instrument: (HACH) 2000 DR spectrophotometer

Ref/ standard method for the examination of water & waste water

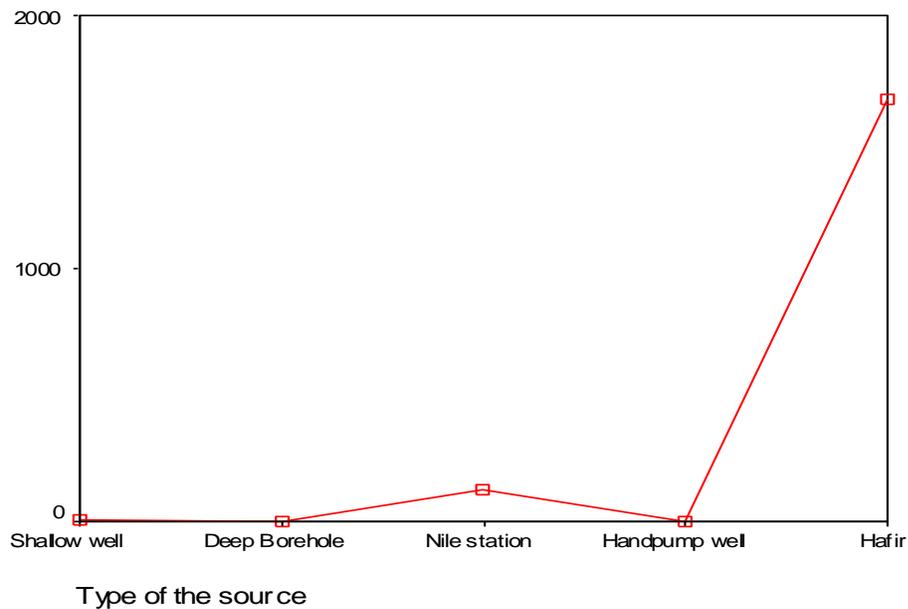
12/ Total dissolved solids (TDS)

Direct reading by using conductivity (TDS) meter Result reported in mg/l (TDS).

Data analysis:

The Epi Info version 3.3.2 was used for data entering and the data had been analyzed by computer; using the statistical package for social sciences (SPSS) version 11.5. Frequency, percentages, cross tabulation associations and differences between means of/ and among samples variables were calculated and compared using X^2 and Fisher's exact tests: a P- value of < 0.05 indicates statistical significance.

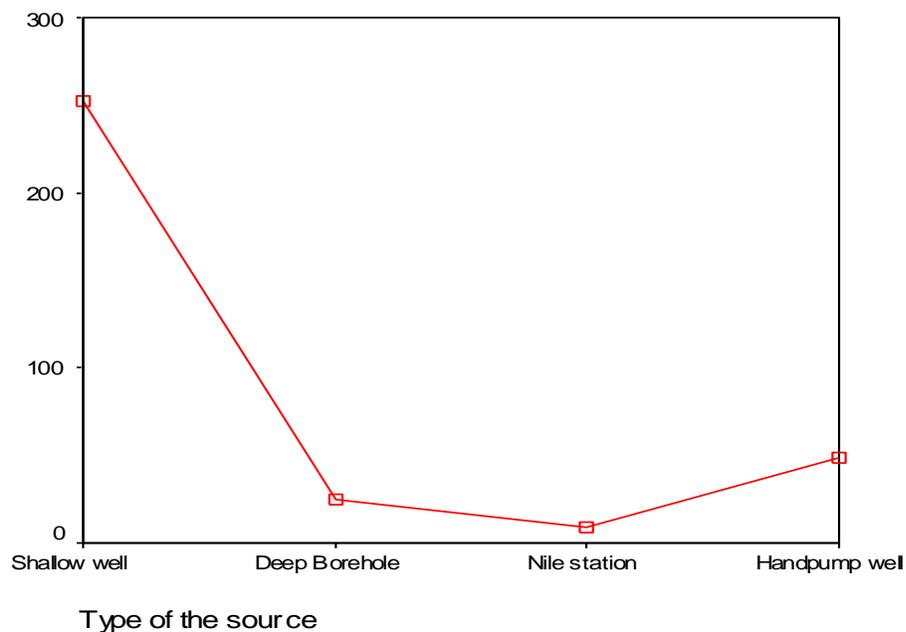
RESULTS AND DISCUSSION



P-value < 0.001

Figure (1) shows the mean differences of turbidity NTU for the selected sources of drinking water

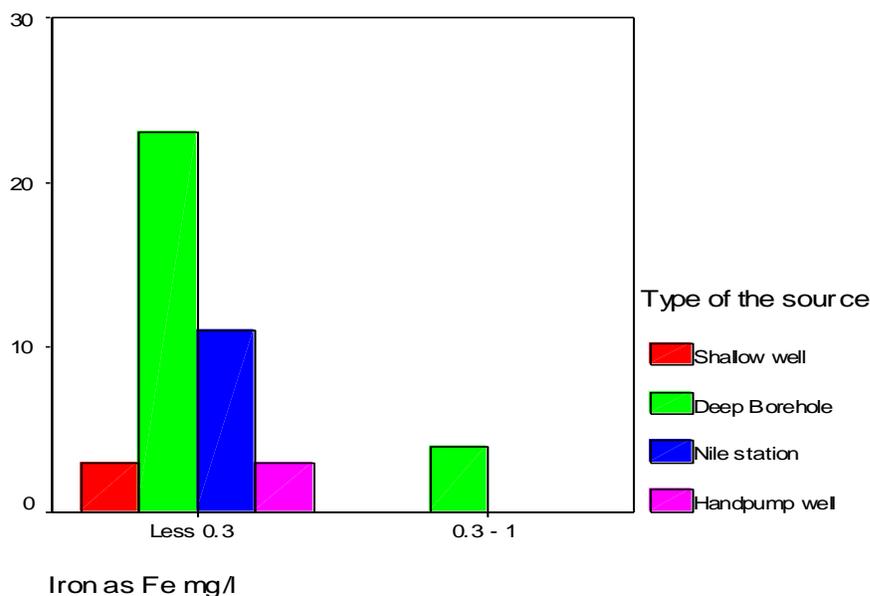
A highly significant difference was found between the means of turbidity among the types of drinking water sources. Hafirs were count the highest level; then Nile station. The ground water was found more cleanly and not turbid as the surface one.



P-value < 0.01

Figure (2) shows the means of sulfate as SO₄ mg/l for the selected sources of drinking water

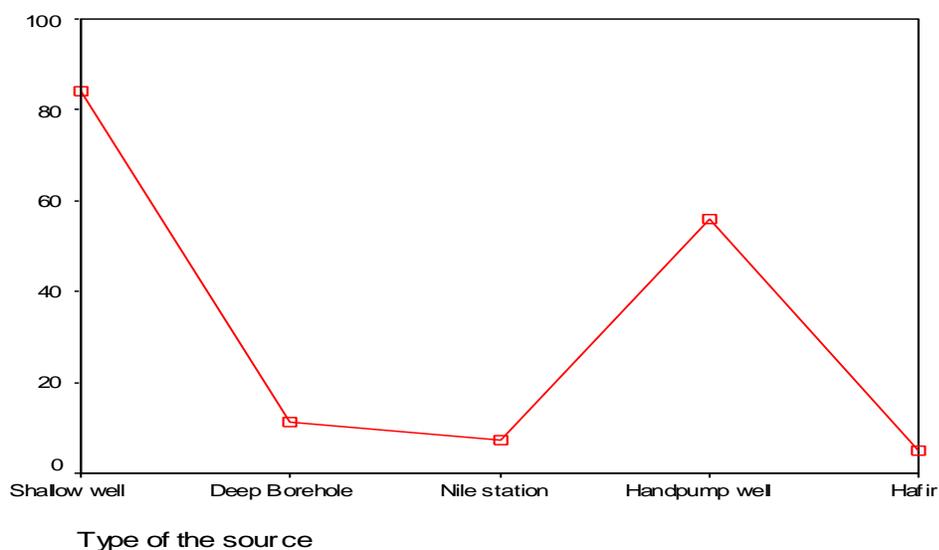
The means of sulfate as SO_4 mg/l for the different type of drinking water showed significant differences due to the type of the sources. Shallow wells count the highest concentration of sulfate as SO_4 . Hand pump, deep wells and Nile stations were counting lowest levels in a descending order.



$P\text{-value} < 0.05$

Figure (3) Analysis for the variant means of iron as Fe mg/l for the selected sources of drinking water

The means concentrations of iron were not significantly associated with the types of drinking water sources. Deep well counted the highest concentration of total iron among the sources.

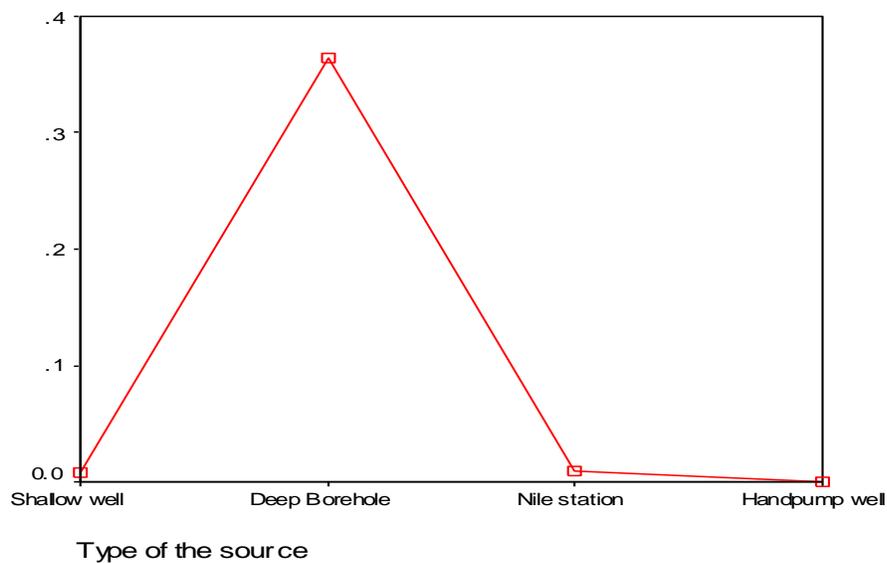


$P\text{-value} < 0.001$

Figure (4) Analysis for the variant means of chloride as cl mg/l for the selected sources of

drinking water

The mean concentration of chloride as *cl mg/l* was highly significantly associated with the types of sources. Shallow wells counted the highest level, also hand pump wells showed high level of chloride.



P-value > 0.05

Figure (5) Analysis for the variant means of Ammonia for the selected sources of drinking water

Shallow wells, Nile stations and hand pump wells showed the lowest levels of ammonia concentrations, it was very high concentrated in the deep wells.

Table (1) Analysis of conductivity $\mu\text{S}/\text{cm}$ for the selected sources of drinking water in Shendi locality

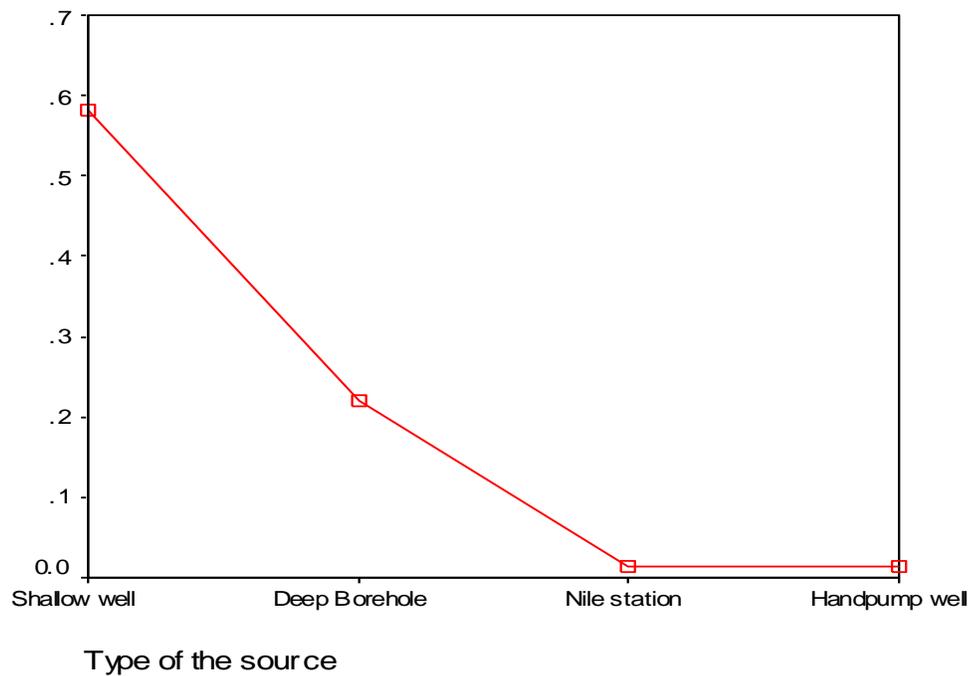
Level of conductivity $\mu\text{S}/\text{cm}$					
Type of the source	count	Frequency	Percent	Valid Percent	Cumulative Percent
Shallow well	501 - 750	2	66.7	66.7	66.7
	> 1000	1	33.3	33.3	100.0
	Total	3	100.0	100.0	
Deep Borehole	Valid 1 - 250	1	3.7	3.7	3.7
	251 - 500	17	63.0	63.0	66.7
	501 - 750	9	33.3	33.3	100.0
	Total	27	100.0	100.0	
Nile station	Valid 1 - 250	2	18.2	18.2	18.2
	251 - 500	9	81.8	81.8	100.0
	Total	11	100.0	100.0	
Handpump well	Valid 251 - 500	1	33.3	33.3	33.3
	501 - 750	1	33.3	33.3	66.7
	> 1000	1	33.3	33.3	100.0
	Total	3	100.0	100.0	
Hafir	Valid 1 - 250	4	100.0	100.0	100.0

Table (2) Association between level of conductivity $\mu\text{S}/\text{cm}$ and the selected types of drinking water sources

Type of the source	Level of conductivity $\mu\text{S}/\text{cm}$				total
	1- 250	251-500	501 -750	>1000	
Shallow well	0	0	2	1	3
Deep borehole	1	17	9		27
Nile station	2	9	0	0	11
Handpump well	0	1	1	1	3
Hafir	0	0	0	4	4
Total	3	27	12	6	48

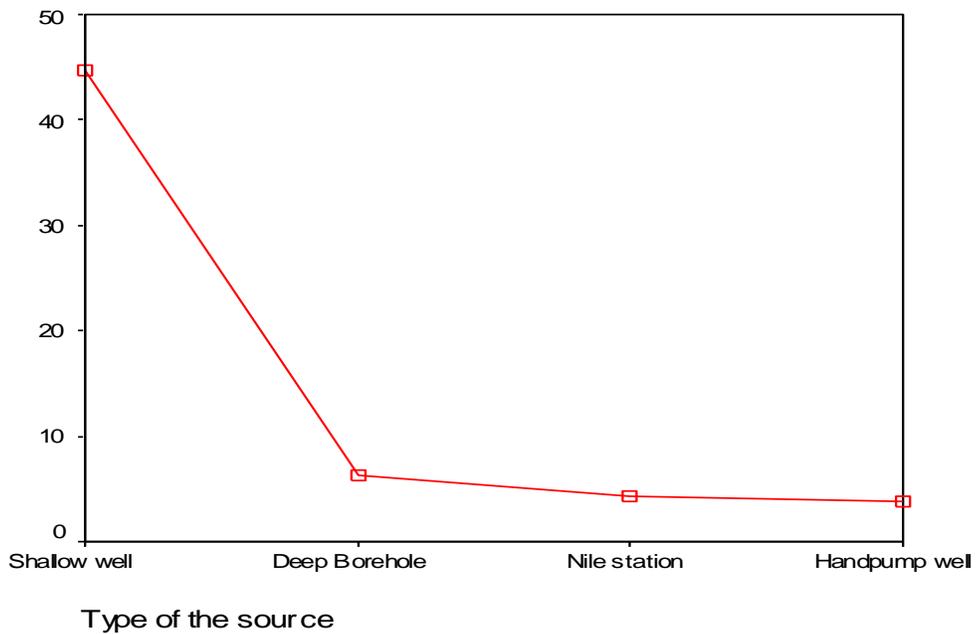
P-value < 0.001

Deep wells and hand pump wells showed a high level of conductivity and it was highest in the first. The differences of means of conductivity were significantly associated to the types for drinking water sources.



P-value < 0.05

Figure (6) Analysis for the variant means of Nitrite as NO₂ mg/l for the selected sources of drinking water



P-value < 0.001

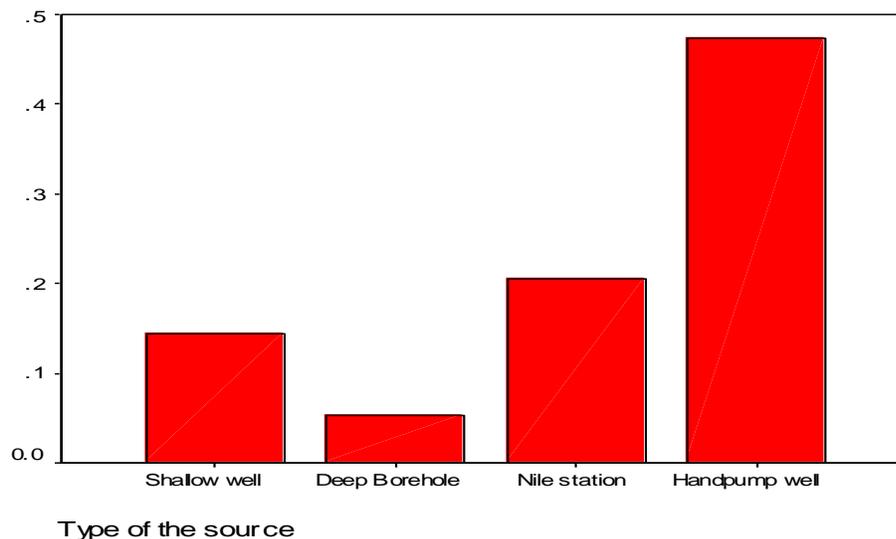
Figure (7) Analysis for the variant means of Nitrate as NO₃ mg/l for the selected sources of drinking water

Nitrite as NO_2 mg/l showed significant difference in mean concentration among the types of drinking water source.

The types of drinking water sources showed a highly significant difference of means consider Nitrate as NO_3 mg/l. Both Nitrite as NO_2 and Nitrate as NO_3 found to be highest in the shallow wells and low in deep Bore holes, Nile station and hand pump wells in descending order respectively.

Table (3) Concentration of Fluoride for the selected sources of drinking water

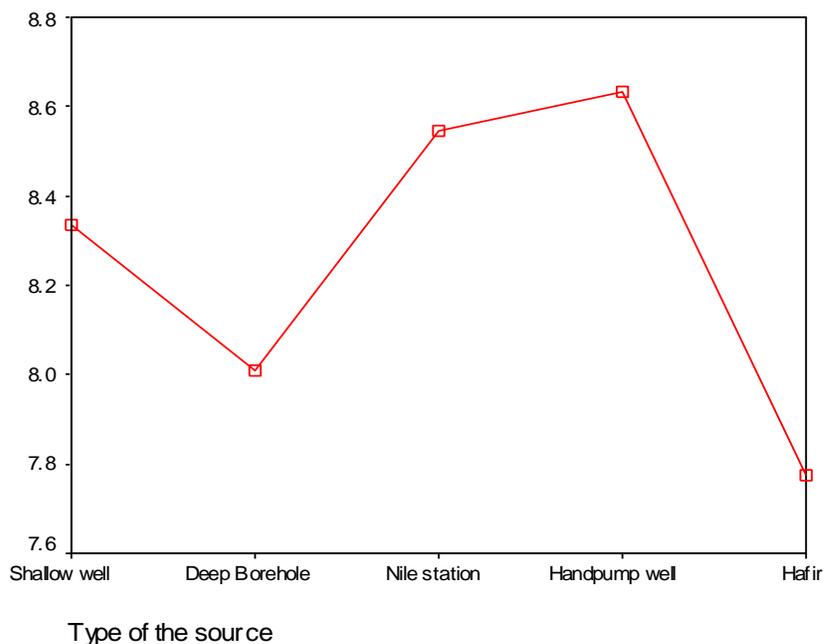
			Fluoride ml/Litre			
Type of the source			Frequency	Percent	Valid Percent	Cumulative Percent
Shallow well	Valid	.000	1	33.3	33.3	33.3
		.180	1	33.3	33.3	66.7
		.250	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Deep Borehole	Valid	.000	19	70.4	70.4	70.4
		.020	1	3.7	3.7	74.1
		.030	2	7.4	7.4	81.5
		.130	2	7.4	7.4	88.9
		.250	1	3.7	3.7	92.6
		.300	1	3.7	3.7	96.3
		.550	1	3.7	3.7	100.0
		Total	27	100.0	100.0	
Nile station	Valid	.000	3	27.3	27.3	27.3
		.140	1	9.1	9.1	36.4
		.180	1	9.1	9.1	45.5
		.270	1	9.1	9.1	54.5
		.290	1	9.1	9.1	63.6
		.330	2	18.2	18.2	81.8
		.360	2	18.2	18.2	100.0
		Total	11	100.0	100.0	
Handpump well	Valid	.290	1	33.3	33.3	33.3
		.520	1	33.3	33.3	66.7
		.610	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Hafir	Missing	System	4	100.0		



$P\text{-value} < 0.001$

Figure (8) Analysis for the variant means of Fluoride mg/l for the selected sources of drinking water associated to their types

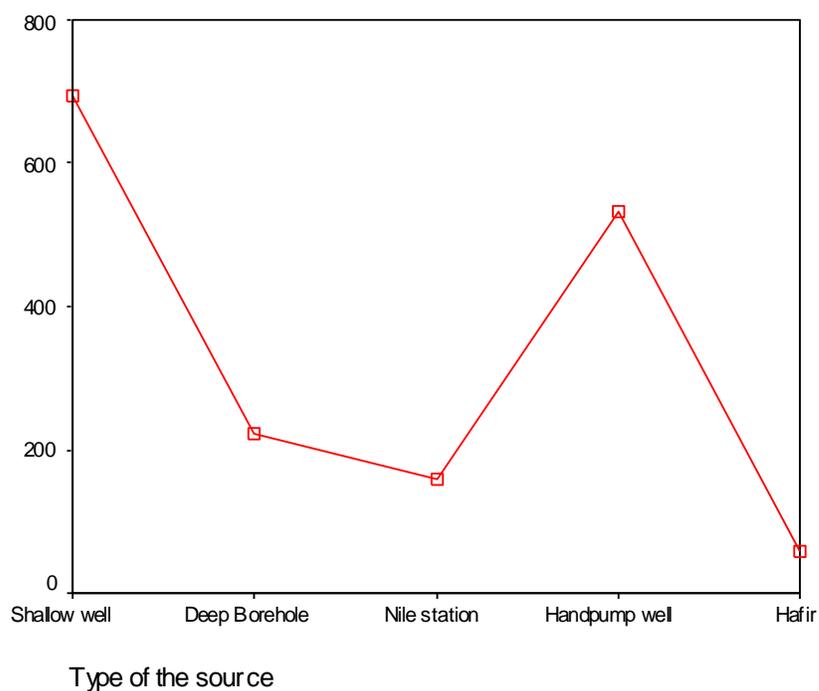
Highly significant difference of fluoride means was observed among the various types of drinking water sources. Hand pump wells counted the highest level.



$P\text{-value} < 0.05$

Figure (9) Analysis for the variant means of pH for the selected sources of drinking water

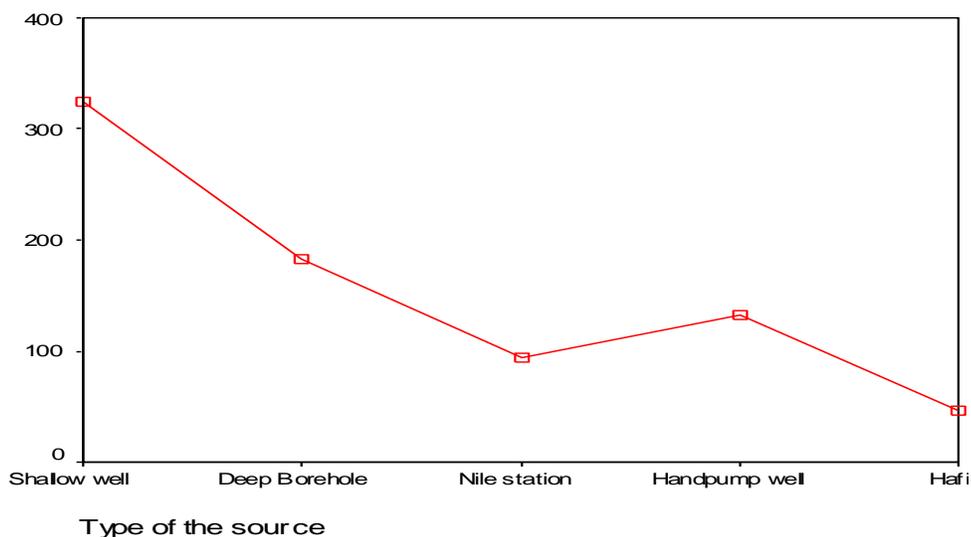
Although all types of drinking water sources were within the accepted normal range of WHO and Sudan, pH level was highest in hand pump wells. The difference between the mean levels for the various types of drinking water sources was not statistically significant.



$P\text{-value} < 0.001$

Figure (10) Analysis for the variant means of total dissolved solid mg/l for the selected sources of drinking water

Difference test of total dissolved solid (TDS) mg/l for the drinking water showed highly significant association with the types of sources. Shallow wells and Hand pump wells count the highest level of (TDS) than the other sources.



$P\text{-value} > 0.05$

Figure (11) Analysis for the variant means of hardness mg/l for the selected sources of drinking water

Shallow wells counted the highest level of hardness, followed by hand pump wells, Nile stations and deep bore holes respectively. The mean level of hardness mg/l was found high in the ground water (shallow, Deep and hand pump wells) compared to Nile stations and Hafirs i.e. the surface water count less hardness.

Table 4: Effect of turbidity/NTU of the drinking water sources on prevalence of most common diseases:

Crosstab

Count			Turbity level NTU/L		Total	
			Less than 5	More than 10		
The area						
urban	Somebody suffering now(Prevalence)	Hepatitis		4	4	
		Diarrhea		3	3	
		Typhoid		8	8	
		Giardiasis		5	5	
		Trachoma		1	1	
		Scabies		1	1	
		Malaria		12	12	
		Dental caries		14	14	
		Mottling of the dental enamel		2	2	
		Cardiovascular diseases		3	3	
		Others		9	9	
		none		28	28	
		Total			90	90
		rural	Somebody suffering now(Prevalence)	Hepatitis	4	7
Poliomyelitis				1	1	
Dysentery	2			3	5	
Diarrhea	4			7	11	
Typhoid	3			11	14	
Giardiasis	2			3	5	
Conjunctivitis	4			7	11	
Ascariasis				3	3	
Scabies				4	4	
Malaria	5			10	15	
Dental caries	17			28	45	
Cardiovascular diseases				2	2	
Others	4			16	20	
none	14			69	83	
Total		59	171	230		

P-value < 0.05

A highly significant difference was found between the mean levels of turbidity associated with the types of drinking water sources (see figure, 1), Hafirs counted the highest level; followed by Nile station. The ground water was found more clean and not turbid as the surface one.

It is observed that the people consuming water of high level turbidity were more suffering from infectious diseases i.e.; the prevalence of the most common diseases was increased with the increasing level of turbidity and this association was statistically significant (see table 4).

From Wikipedia, the free encyclopedia,{21:00, 18 November (2006) (UTC)} Retrieved from "Measurement of Turbidity is a key test of water quality. The higher the turbidity, the higher the risk of drinkers developing gastrointestinal diseases, especially for immune-compromised people, because contaminants like virus or bacteria can become attached to the suspended solid. The suspended solid interfere with water disinfection by chlorine because the particles act as shields for the virus and bacteria. High water turbidity is the leading cause of gastrointestinal cancer in the United States [Pink Daniel H.Yahoo.April19, 2006].

The means of sulfate as SO_4 mg/l for the variance type of drinking water showed significant differences due to the type of sources. Shallow wells count the highest concentration of sulfate as SO_4 (see Figure (2)).

The mean differences of iron were significantly associated with the types of drinking water sources. Deep wells counted the highest concentration of total iron among the sources (see Figure (3)

As Figure (4) shown: The mean concentration of chloride as *cl* mg/l was found to be highly associated with the types of sources. Water from ground sources showed high level of chloride more than the Sudan standard (SSMO, 2003), which prescribed for chloride (200 mg/ litre. The maximum permissible level is 600 mg/litre).

It was found to be highest in the shallow wells, hand pump wells and deep wells; specifically among the contaminated once Ammonia was very concentrated in deep wells (see figure (5).

Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution.

Ground water source register highest mean of conductivity than the surface sources. The differences of means of conductivity were significantly associated with the types of drinking water sources (see table (1&2)).

The electrical properties observable in deep groundwater can be related to the concentration of ions and mineral salts as shown above and carbon dioxide dissolved in it. Pure water can also be electrolyzed into oxygen and hydrogen gases but in the absence of dissolved ions this is a very slow process and thus very little current is conducted.

The types of drinking water sources showed significant difference of mean nitrite as NO_2 mg/l & a highly significant difference of means for nitrate as NO_3 mg/l. Both Nitrite as NO_2 and Nitrate as NO_3 found to be highest in the shallow wells (see figure, 6 & 7). Nitrate is also of concern although there remains uncertainty about the scale of adverse health effects from nitrate as few countries include methemaglobinaemia as a notefailable disease (Saywell, 1999). Raised nitrate is, however, identified as a potential public health problem in countries where concentrations in groundwater reach extremely high values (Melian et al., 1997).

While nitrate is much less toxic than ammonia or nitrite, levels over 30 ppm of nitrate can inhibit growth, impair the immune system. "The principal pathway of entering aquatic systems is through surface runoff from agricultural or landscaped areas which have received excess nitrate fertilizer."04:36, 19 January 2007 (UTC) retrieved from "http://en.wikipedia.org/wiki/Talk:Nitrate" Highly significant difference of fluoride means was observed among the various types of drinking water sources (Table (3) & figure, 8). The presence of fluoride at about 1 mg/litre in drinking water is known to protect against dental carries, but high levels of fluoride cause mottling of the dental enamel.

Also it was found that Fluoride level was very significantly associated with the dental carries, which were more common among those drinking from sources with very low level or very high level of fluoride above or below the standard level described by WHO (see appendix 6-19). These results go with the Smith *et al.*, (2000) who mentioned that: disease may also result from consumption of water containing toxic levels of chemicals. The health burden is most significant for two chemicals: arsenic and fluoride. The total disease burden is as yet unknown, but in Bangladesh, the country with the most widely reported problem, between 35 and 77 million people are at potential risk. Fluoride is also a significant global problem and WHO (1999) suggested that over 60 million people are affected by fluorosis in India and China and suggested the total globally population affected as being 70 million

Although all types of drinking water sources were within the accepted normal standard range considering pH (9), the difference between the means level for the various types of drinking water sources was not statistically significant.

PH of the source of drinking water was very significant in the urban and highly significant in the rural areas of Shendi with the prevalence of the most common diseases. This may be due to the influence of the acidity and alkalinity on the viability of pathogens in drinking water.

Difference test of total dissolved solid (TDS) mg/l for the drinking water showed highly significant association with the types of sources (see figure (10)). Subsurface shallow water, count the highest level of (TDS) see figure (10)).

Total dissolved solids (TDS) can have an important effect on the taste of drinking water. The palatability of water with a TDS level of less than 600 mg/litre is generally considered to be good. Drinking water becomes increasingly unpalatable at TDS levels greater than 1200 mg/litre. Water with extremely low concentration of TDS may be unacceptable because of its flat, insipid taste.

As figure (11) shown: The mean level of hardness mg/l was found high in the ground water in Shendi locality compared to Nile stations and Hafirs i.e. the surface water.

Water hardness as mentioned in Dietary Reference Intakes and Vaclacik & Christian, (2003) is a critical factor in food processing. It can dramatically affect the quality of a product as well as playing a role in sanitation. The hardness of water also affects its pH balance which plays a critical role in food processing. For example, hard water prevents successful production of clear beverages. Water hardness also affects sanitation; with increasing hardness, there is a loss of effectiveness for its use as a sanitizer.

CONCLUSION

Physical and Chemical quality:

Although the mean difference of hardness between the various types of drinking water sources was statistically not significant; surface water counted less hardness compared to the ground water especially that of the shallow wells which, was a critical factor in food processing. Water hardness also affects sanitation; with increasing hardness, there is a loss of effectiveness for its use as a sanitizer. It was observed that the people, who were consuming water of high turbidity level in Shendi locality, were suffering more than others from infectious diseases. The higher the turbidity, the higher the risk of drinkers developing diseases, because contaminants like virus or bacteria can become attached to the suspended solid. Ammonia concentrations, was highest in the deep wells (specially the contaminated wells). Also it was found that Fluoride levels were significantly associated with the dental carries, which were more common among those drinking from sources with elevated level level of fluoride from the normal standard level described by WHO. The provision of drinking water that is not only safe but also acceptable (pleasing) in appearance, taste and odor is a matter of high priority. The supply of water that is unsatisfactory in this respect will undermine the confidence of consumers, leading to use of water from less safe sources.

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