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*Review*

# Groundwater: Characteristics, qualities, pollutions and treatments: An overview

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**This review considered groundwater resources, its characteristics, qualities, pollutions and available treatments. Groundwater refers to all the water occupying the voids, pores and fissures within geological formations, which originated from atmospheric precipitation either directly by rainfall infiltration or indirectly from rivers, lakes or canals. The chemical, physical and bacterial characteristics of groundwater determine its usefulness for various purposes. The ground water analysis reviewed includes pH, chlorine content, total dissolved solids (TDS), turbidity, dissolved oxygen and hardness others include alkalinity, chloride, toxic chemicals and the presence of coli form organisms. The treatments considered are; aeration, coagulation, flocculation, sedimentation and filtration. Appropriate technology methods such as container storage, pot chlorination, boiling and solar disinfection were discovered to be in use. The paper concluded by recommending research into quantifying groundwater, its quality and treatment based on the above overview.**

**Keywords:** groundwater quality, aeration, coagulation, sedimentation, disinfection.

## INTRODUCTION

Groundwater refers to all the water occupying the voids, pores and fissures within geological formations, which originated from atmospheric precipitation either directly by rainfall infiltration or indirectly from rivers, lakes or canals. Sands, gravel, sandstones, and limestone formations are the usual sources of groundwater supply though some may be drawn from impervious rocks such as granite when they have an over burden of sand or gravel.

Groundwater is a valued fresh water resource and constitutes about two-third of the fresh water reserves of the world (Chilton, 1992). Buchanan (1983) also estimated. the groundwater reservoir of the world at about $5.0 \times 10^{24}$ L, this volume is more than 2,000 times the volume of waters in all the world's rivers and more than 30 times the volume contained in all the world's fresh water lakes.

Groundwater is used for agricultural, industrial and domestic purposes. It accounts for about 50% of livestock and irrigation usage and just under 40% of water supplies, whilst in rural areas, 98% of domestic water use is from groundwater (Todd, 1980).

Utilization of groundwater as a source for domestic, municipal, agricultural and industrial activities continue to increase principally because of the heavy capital outlay and maintenance of surface water development through Dams especially in developing countries (Sangodoyin and Agbawhe, 1992).

Another factor which is responsible for the attention being diverted to this source is improved technology manifest by deep boring in form of borehole which satisfies WHO drinking water quality standard (Osot, 2000).

Groundwater is abstracted through hand-dug wells; hand-pump operated shallow-wells and submersible pump operated deep well or boreholes (Ojo, 2002). Groundwater is often high in mineral content such as magnesium and calcium salts, iron and manganese depending on the chemical composition of the stratum through which the rock flows (Todd, 1980).

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Oluwande (1983) identified water hole as the oldest means of obtaining sub-surface water. Water holes were classified into four types that demand full conventional treatment before use. Wells are holes in the ground that intersect the water table as water bearing rocks flowing as aquifers.

Park and Park (1994) divided wells into two namely shallow and deep wells depending on the location of the impervious strata for which the water is obtained. Also, based on the mode of construction, wells can be classified into three categories namely:

1. Hand-dug well
2. Bored well
3. Driven well (Sangodoyin, 1987).

Shallow wells are generally less than 15 m deep while deep well are greater than 50 m in depth (Hofkes, 1981). They both exhibit differences in bacteriological quality and yield, with the water becoming purer and more constant with increase in depth. Deep wells are usually boreholes with depth above 100 and 150 m diameter especially in the sedimentary formations (Ojo, 2002). They serve large communities due to their high yield, but with high cost of construction and maintenance. Deep well maintenance and rehabilitation are very important because of the tendencies for the well screen being clogged and corroded, thus reducing its effectiveness and efficiency.

Hand dug wells as the name implies are constructed manually and are little more than irregular hole in the ground, intersecting the water table (Todd, 1980). They are prone to pollution from air borne materials, run-off from the surface, though their sanitary status may be improved by including certain features such as lining with cement ring or metal ring (Drum), cover (wooden or metal), apron and drain. Todd (1980) gave an approximate yield of a properly constructed well to be between 2,500 to 7,500 $m^3$ per day, but most domestic hand dug well yield less than 500 $m^3$/day

Groundwater pollution, also referred to as groundwater contamination, is not as easily classified as surface water pollution. Because of its nature, groundwater aquifers are susceptible to contamination from sources that may not directly affect surface water bodies, and the distinction of point vs. non-point source may be irrelevant. Analysis of groundwater contamination may focus on the soil characteristics and site geology, hydrogeology, hydrology, and the nature of the contaminants.

Contaminants leading to pollution in groundwater include a wide spectrum of chemicals, pathogens, and physical or sensory changes such as elevated temperature and discoloration.

High concentrations of naturally-occurring substances like calcium, sodium, iron, manganese, etc can have negative impacts on aquatic flora and fauna. Their concentration is the key in determining what a natural component of water is, and what a contaminant is. Other natural and anthropogenic substances may cause turbidity and other negative effects (EPA, 2005).

Groundwater treatment is the process of converting raw water from sub-surface source into a potable form that is suitable for drinking and other domestic uses. It also entails the removal of pathogenic organisms and toxic substances. The method of treatment will depend of the pollution or contaminants involved. The convection methods by which water is made potable are namely; Aeration, coagulation, flocculation, sedimentation, filtration and other means of disinfection which make use of physical processes to achieve their objectives. The improvement of water quality through low-cost treatment processes thus reducing the incidence of water borne diseases is inevitable. Some of the appropriate technologies being used include: Pot storage, pot chlorination, disinfection among others (Ojo et al., 2011).

## GROUNDWATER QUALITY

The chemical, physical and bacterial characteristics of groundwater determine its usefulness for various purposes. Chemical analysis of groundwater includes the determination of the concentrations of inorganic constituent. The analysis also includes measurement of pH and specific electrical conductance.

Temperature, colour, turbidity, odour and taste are evaluated in a physical analysis (Table 1). Bacteria analysis generally consists of tests to detect the presence of coli form organisms.

Tebbute (1992) noted that pathogenic organisms are rarely found in groundwater, since poor well construction or being associated with bedrock aquifers in which large openings afford direct connection between the surface and groundwater causes most well pathogenic contamination.

Lloyd and Helmer (1991) observed that the water quality problem may be associated with and traceable to, any or all of the following:

1. Poor quality source of water,
2. Poor site selection or protection such as apron and lining
3. Construction difficulties and
4. Structural deterioration with age

### *Microbial quality*

Safe guarding the microbial quality of drinking water is said by the experts to be the most important objective, even ahead of its physical and chemical quality, since water represents an obvious mode of transmission of enteric diseases (Bland, 1980; Skinner and Shecon, 1997). According to the WHO (1971), the greatest danger

**Table 1.** Drinking water quality.

| Parameters (1) | Undesirable effect produced (2) | Highest desirable level (3) | Minimum permissible level (4) |
|---|---|---|---|
| **A. Physical** | | | |
| Colour (Units) | Discolouration odour | 5 | 50 |
| Odour | Taste | Unobjectionable | Unobjectionable |
| | Gastrointestinal | Unobjectionable | Unobjectionable |
| Total Solida (mg/l) | Irritation | 500 | 1500 |
| Suspended | Turbidity | | |
| Matter | Gastrointestination | | |
| (Units) | Irritations | 5 | 25 |
| **B. Chemicals** | | | |
| pH (Units) | Taste, excessive scale formation | 7.0 to 8.5 | 6.5 to 9.2 |
| Calcium (mg/l) | Taste, corrosion in hot water system | 75 | 200 |
| Chloride (mg/l) | Mottling of teeth Disfiguring of skeletons. | 200 | 600 |
| Fluoride (mg/l) | Excessive scale formation | 1.0 | 1.5 |
| Total hardness as mg/l of $CaCO_3$ | Taste odour | 100 | 500 |
| Mineral oil (mg/l) | Taste | | |
| Phenolic subs. (mg/l) Toxic | Toxic | 0.01 | 0.30 |
| **C. Trace elements** | | | |
| Copper (mg/l) | A stringent taste, discolouration, corrosion of pipe fittings and utensils | 0.05 | 0.05 |
| Cyanide (mg/l) | Toxic | | |
| Iron (mg/l) | Taste, discolouration constipation turbidity growth of bacteria | 0.1 | 0.05 |
| Lead (mg/l) | Toxic | | 0.1 |
| Manganese (mg/l) | Taste, discolouration, turbidity, deposits in pipes | 0.05 | 0.05 |
| Zinc | A stringent taste | 5.0 | 15.0 |
| **D. Pesticides** | | | |
| DDT (mg/l) | Toxic | | 0.05 |
| PCB | Toxic | | NIL |

Source: WHO drinking water quality standard (1991).

associated with drinking water is contamination by sewage, human and animal excreta. Microbial qualify is determined using various methods of bacterial examination. The indication organism's method as invented by Percy Frankland in Londom in 1981 is basically the concept of using organisms usually abundant in human and animal excrement, as evidence of contamination and possible presence of other potentially dangerous microorganisms (WHO, 1984).

The use of indicator organisms for determination of the microbial quality of water saves the time, labour and expenses involved in attempting to test for all pathogens that a water sample might possible contain. For an organism to be ideal for use as an indicator, it must meet the following criteria:

1. The method of isolation, identification and enumeration should be simple and unambiguous.
2. It should be resistant to chlorine and have a higher survival rate in water than pathogens.
3. It should be more neutral than all pathogens in the environment.

The significant that can be attached to the presence or absence of a particular fecal indicator varies with each organism and with the degree to which that organism can

**Table 2.** Taste threshold for major cations.

| Element | Taste threshold mg/l |
|---|---|
| Calcium | 100 |
| Magnesium | 30 |
| Sodium | 100 |
| Potassium | 300 |
| Iron II | 0.4 in distilled water |
| Iron III | 0.12 in distilled water |
| Zinc | 4.3 in distilled water |
| Zinc | 6.8 in mineralized water |

Source: WHO, 1984.

be specifically associated with faeces (WHO, 1984).

The WHO (1984) recommended standards for testing contamination during transportation or storage is an MPN count of less than 10 per 100 ml for total coli forms and 2.5 per 100 ml for *E. coli.*

The body also recommends that the widespread of faecal contamination in developing countries, the nation surveillance agency should set medium term targets for the progressive improvement of water supplies.

### *Physicochemical quality*

The term physicochemical quality is used in reference to the characteristics of water which may affect its acceptability due to aesthetic considerations such as colour and taste; produce toxicity reactions, unexpected physiological responses of laxative effect, and objectionable effects during normal use such as curdy precipitates (WHO, 1995).

**Taste and odour:** Taste and odour depend on the stimulation of the human receptor cells, which are located in the taste-buds for taste and nasal cavity for odour (WHO, 1984). Taste and odour are complimentary, for example when tasting water; both the olfactory and gustatory nerves are active. In all taste it is actually flavour that is being measured flavour refers to the combination of taste, odour, temperature and feel. The close association between taste and odour may be illustrated by the lack of flavour of many food substances, when the sense of smell is lost during a head cold (Emslie-smith, 1988).

Taste and odour problems account for the largest single class of consumer complaints in drinking water supplies, due to the water source, the treatment method, distribution system or a combination of all three (WHO, 1984). Taste in drinking water is measured by taste tests such as the threshold test or taste rating tests. The odour tests are carried out for odour in drinking water (Table 2). The sense of smell is more sensitive than the best analytical method, for example the guideline for cyanide in drinking water would be 1/100$^{th}$ of the present limit if based on the odour threshold of 0.001 mg/l (WHO, 1984). Factors affecting taste and odour include:

**Temperature:** The growth rate of microorganisms, some of which produce bad tasting metabolites is positively associated with temperature. The odour of substance is also temperature influenced because of relationship between odour and vapour pressure, therefore odour measurement usually specify temperature.

**pH:** pH influences the taste and odour of a substance significantly, especially when it controls the equilibrium concentration of the neutral and ionized forms of a substance in solution. The average threshold increases form 0.075 to 0.450 mg/l as the pH increases from 5.0 to 9.0 (WHO, 1984).

**Residual chlorine:** A balance is sought such that the level of residual chlorine is high enough for microbial safety without leaving an objectionable taste in drinking water.

**Total dissolved solids (TDS):** Total Dissolved solids comprise of organic matter and inorganic salts, which may originate from sources such as sewage, effluent discharge, urban run-off or from natural bicarbonates, chlorides, sulphate, nitrate, sodium, potassium, calcium and magnesium. The major determinant of the TDS level in water is the geochemical characteristics of the ground it comes in contact with, for example granite and silicons sands, and well leached soils have TDS less than 360 mg/l, the WHO (1984) gave the palatability of drinking water according to its TDS level with rating given by Bruvold as less than 500 mg/l s excellent level and greater than 1700 mg/l as unacceptable (Table 3). TDS is related to other water quality parameters like hardness, which may occur if the high TDS content is due to the presence of carbonates.

**Turbidity:** Turbidity is an expression of certain light scattering and light absorbing properties of the water sample caused by the presence of clay, silt, suspended matter, colloidal particles, plankton and other micro-organisms (WHO, 1984). Turbidity can be measured by turbidity and nephelometry. Turbidity of water affects other water quality parameters such as colour, when it is imparted by colloidal particles. It also promotes the microbial proliferation, thus affecting negatively the microbiological quality of water. It also affects the chemical quality of drinking water through the formation of complexes between the turbidity causing humic matter and heavy metals (WHO, 1984).

**Colour:** Colour in drinking water is caused by the presences of coloured organic substances, usually humic, which originate from the decay of vegetation in

**Table 3**. TDS level of drinking water for consumer ratings.

| Rating | TDS levels (mg/l) |
|---|---|
| Excellent | <300 |
| Good | 300-600 |
| Poor | 600-900 |
| Unacceptable | >1700 |

Source: WHO, 1984.

surface water. Iron and manganese also give water a red and blue colour respectively by the action of bacteria, which oxidize them to their ferric and manganic oxides respectively. Colour is measured by visual comparison of the sample with platinum cabalt standards where one unit of colour is that produce by 1 mg/l platinum of chloraplatinate ion. The WHO (1984) recommends a limit of 15 TCU drinking water.

**Dissolve oxygen:** The level of dissolved oxygen in water is used as an indication of pollution and its potability. This thus forms a key test in water pollution control activities and waste treatment process control activities and waste treatment process control. The recommended guideline value for drinking water is a level not below 8 mg/l (WHO, 1984). Lower levels indicate microbial contamination or corrosion.

**Hardness:** This is simply the resistance of water in forming lather with soap. Hard water thus requires a considerable amount of soap to produce lather. The principal ions causing hardness are calcium and magnesium. When the anion is carbonate, it is referred to as temperature, since it can be removed by boiling, unlike when the anions are sulfates, chlorides and nitrates. Groundwater is often harder than surface water and may have levels up to several thousand mg/l because of it high solubilizing potentials, particularly for rocks containing gypsum, calcite and dolomite. Source of hardness include sewage and run-off from soils particularly limestone formations, building materials containing calcium oxide and textile and paper materials containing magnesium.

**Alkalinity:** Alkalinity is an index of the buffering capacity of water produced anions of weak acids, like hydroxides, bicarbonates and carbonates. An increase in alkalinity causes a loss of colour, which is directly proportional to the alkalinity of the water sample and is usually close to its hardness value.

**Chloride:** Chloride occurs in groundwater as a result of saline infrusion, brine in oil well operations, sewage discharge, irrigation water being drained, and contamination from refuse leachate. The WHO (1984) recommends a guideline value of 250 mg/l any higher value than 1000 mg/l is an indication of polluted water with chloride.

### *Toxic chemicals*

Chemical contaminations of drinking water supplies occur along with contaminants of other inorganic and organic constituents.

**Nitrates and nitrites:** They are considered together because conversion from one form to the other occurs in the environment and the health effects of nitrates are generally as a consequence of its ready conversion to nitrites in the body. The WHO (1984) guideline for nitrates in drinking water are typically below 50 mg of nitrate-N per litre, levels exceeding these are indicative of pollution. Nitrite levels can be reduced doing water treatment by the oxidizing effects of chlorine.

**Lead:** Lead is a natural constituent of the earth crust at an average concentration of about 16 mg/kg. Lead levels in drinking water are relatively low, because convectional water treatment procedures remove a significant amount of lead. Low pH and softness increases lead content of water by promotion corrosion. The maximum intake of lead from food, air and water is 3 mg/week (0.05 mg/kg of body weight) for adults (WHO, 1984).

**Iron:** Iron is the most abundant element by weight in the crust, it occurs in water in its ferric and ferrous states, particularly in well-aerated conditions. Rock and mineral dissolution acid mine drainage, land fill leachates, sewage and iron related industries are causes of high iron levels in groundwater, lakes and reservoirs, particularly where reducing conditions are present (Okun, 1983).

**Others:** Other toxic chemicals include Ammonia in non-ionized form ($NH_3$) and ionized form ($NH_4^+$); arsenic, asbestos, barium, boron, cadmium, chromium, copper and aluminum. Others include fluoride, mercury and organic contaminants.

## Sources of pollution

Water is said to be polluted when its quality is degraded as a result of man's activities to an extent that it becomes less suitable for its intended use (Chapman, 1992). The foreign substances that impair or degrade the water quality are referred to as pollutants and may be of organic, inorganic, biological or physical origin. The deleterious effect of pollutions include harm to human health, hindrance to aquatic activities and the inability of the water to support agriculture, industrial and other related economic activities. A noted source of pollution in groundwater supplies is the latrine/septic tank, causing an increase in biochemical oxygen demand BOD, chemical *oxygen demand* COD, nitrate, inorganic chemicals and pathogens thus leading to outbreak of diseases common in developing nations like Africa, Asia and South America (Chapman, 1992). Sangodoyin (1993) observed that the unsanitary mode of disposal of wastes, such as defecation in streams and the dumping of refuse in pits, rivers and drainage channels as seen in most Nigerian urban settlements, could be expected to affect surface and groundwater quality. The degree of pollution (contamination) will depend on the efficiency of the waste disposal methods, safety of land use patterns, density of disposal systems in an area, composition of waste and soil and a number of other site-specific information. Well liming eliminates contamination and hence improves water quality (Sangodoyin, 1993). Industrial waste disposal method of discharging effluents unto land, stream and sanitation sewers also have potential of polluting ground water. Other sources of groundwater pollution include tank and pipeline leakage and mining activities.

Oil and gas production is often accompanied by substantial discharges of wastewater called brine, which is disposed of using methods such as abandoned pits, evaporation ponds and streams.

These methods have the potential of polluting aquifers with brine, leading to an increase in sodium, calcium, ammonia, boron, chlorides, sulfates, trace metals and substantial amounts of total solids (Chapman, 1992).

Agricultural sources of pollution include irrigation with a lot of return flow back into the ground (Ogedengbe, 1980). The possible effect on the ground water include an increase in ground water salinity, due to inadequate drainage and direct evapotranspiration of irrigation return-flow from soils whose salinity has been increased by salts from fertilizers (Todd, 1980; Chapman, 1992).

Others include animal waste from animal pens and slaughter houses where they are confined for purposes of meat and milk production and may carry through storm run-offs, significant amounts of nitrates, salts, organic loads and bacteria to surface and sub-surface water (Sangodoyin and Agbawhe, 1991). Agrochemicals such as fertilizer, pesticides and insecticides also pollute ground water. Nitrate based fertilizers are a significant contribution to groundwater pollution. This is because nitrogen in solution is neither fully utilized by plants nor absorbed by the soils. Stock piles of solid materials from construction sites, individual's plants residue are potential groundwater pollutants when precipitation falls on these piles, causing a leaching of heavy metals, salts and other organic and inorganic constituents.

Sangodoyin (1987) gave the following considerations as a way of reducing groundwater contamination or pollution:

1. A well should be sited uphill of a polluting source. This is with a view to diverting to drain from the well into a polluting source rather than converse.
2. The distance between a well and a polluting source should not less than 30 m (100 feet).
3. Well construction should start towards the end of the dry season.

## WATER TREATMENT

Water treatment is the process of converting raw water from surface or sub-surface source into a potable form that is suitable for drinking and other domestic uses (Hofkes, 1981). It also entails the removal of pathogenic organisms and toxic substances listed earlier, but do not necessarily make the drinking water pure or sterile in the analytical sense (Oluwande, 1983).

The convection methods by which water is made potable are namely; aeration, coagulation, flocculation, sedimentation, filtration and other means of disinfection which make use of physical processes to achieve their objectives.

### Aeration

In Aeration, water is brought into intimate contact with air in order to increase their oxygen content to facilitate precipitation and result in the removal of iron and manganese in their ferric and manganese forms, and organic compounds. Aeration reduces the carbon dioxide content of water and thus decreasing the solubilization tendencies of water, which causes corrosion and leaching of plumbing materials into water. Ground high is iron and manganese benefit from aeration (Sangodoyin, 1987).

### Coagulation and flocculation

This is the addition of Alum $(Al_2(SO_4)_3.14H_2O$, thus forming colloids with size similar to those of bacteria (Sangodoyin, 1987). Coagulation ensures the gathering together of small size particles into bigger ones with higher setting velocity or sedimentation. The sludge formed can than be disposed off. Coagulation reduces load on filters, thereby reducing costs through the extension of the life of the filter.

### Sedimentation

This is known as clarification and is the unit process where particles heavier than the liquid they are in are removed by gravitational settling. Sedimentation affects the chemical quality of water, through the settling of complexes formed between heavy metals and flocs (Sangodoyin, 1987).

### Filtration

This is a process designed to remove bacteria, debris and organic matter. It is often considered as the final polishing operation in water treatment. When sand is used as a medium, it is called slow sand filtration, which is often employed in developing nations. It does not work for high turbidity water since it can get clogged easily (Sangodoyin, 1987).

In sand filtration there is complete physical, chemical and biological treatment in one unit. The demerit in slow sand filters is that of requirement of extensive bed areas and non-availability of graded sand and labour intensive clearing operation. Recent studies have showed the workability of ground coconut shells and rice husks to arrest the problem of sand (Sangodoyin, 1987). Other type of filters includes; rapid pressure filter and gravity filters.

## Appropriate technology for water treatment

The failure of transferred technology from developed nations to developing nations in achieving the desired result of being easily adaptable and affordable due to non-availability of spare parts, skill (technical know how) and maintenance, often result into the development of appropriate local technology. The improvement of water quality through low-cost treatment processes thus reducing the incidence of water borne diseases is inevitable. The following had been experimented:

### *Storage*

Sangodoyin and Osuji (1990) observed experimentally that 7 days of storage can kill about 90% of coli form in contaminated water which is reasonably clear and on which ultra-violent light is incident deeply. The storage facilities also lead to improvement in turbidity. This is accomplished during storage through sedimentation process, leading to excessive accumulation of solids for which pressure must be for removal. Storage facilities must have a screen at the inlet to remove snails and other like objects thereby ensuring adequate detention time, without short-circuiting. Providing bafflers ensure this.

### *Pot chlorination*

This refers to the disinfection of well water by placing a vessel containing a mixture of chlorine powder and sand in the well, a 1.5 kg of chlorine will provide satisfactory disinfection for one week (Hofkesi, 1981).

Pot chlorination might be either single or double pot where the single pot is found to give too high a chlorine content to the water. The double pot is effective for 2 weeks, in a well with a 4,500 L capacity drawn at a rate of 400 to 500 L day$^{-1}$.

### *Disinfection*

Disinfection is simply the killing of potentially harmful organisms. Its objective is to obtain microbiologically clean water, which contains no pathogenic organisms and is free from biological forms that may be harmful to human health or aesthetically objectionable (Kootapep et al., 1980).

Chemical disinfections employ the use of chemical called disinfecting agents, for example chlorine, ozone, potassium permanganate and chlorine dioxide.

Hofkes (1981) notes that for a chemical to be suitable for use as a disinfectant, it should satisfy the following conditions:

1. Be quick and effective in killing pathogens present in water
2. Be readily soluble in the water concentrations required for disinfection
3. It should leave a residual
4. It should impart no taste, odour or colour to the disinfected water.
5. It should be easy to detect and measure in water
6. It should be readily available at moderate cost.

**Theory of disinfection:** In general, the rate of kill is given by

$$\frac{dN}{dt} = -kN \tag{1}$$

where, K = reaction rate constant for particular disinfection and N = number of viable organisms

On integrating,

$$\log_e \frac{Nt}{N_o} = -Kt \tag{2}$$

where $N_o$ = number of organisms initially and $N_t$ = number of organisms at time t.

Charging to base 10

$$\log \frac{Nt}{N_0} = -Kt$$

where K = 0.4343K

or

$$t = \frac{1}{K} \log \frac{N_0}{N_t} \tag{3}$$

Since $N_t$ will never reach zero it is normal to specific kill as a percentage, e.g. 99.9%. The rate constant as well as depending on the particular disinfection also varies with disinfectant concentration, temperature, pH and other environment factors (Tebbutt, 1992).

The most popular disinfectant for water is chlorine, which does not obey Equation (1), but follows the relationship;

$$\frac{dN}{dt} = KN_t$$

On integrating and changing to base 10 gives,

$$r^2 = \frac{2}{K}\log\frac{No}{N_t}$$

At pH 7, valves of K for chlorine are about 1.6 x $10^{-2}$/s for free residuals and 1.6 x $10^{-5}$/s for combined residuals, when applied to coli form organisms.

According to Acra et al. (1990), the technique make use of the either the batch process in which discrete units of water are exposed in various containers like plastic bowls and bottles or continuous flow systems in which an attempt is made to maintain a uniform flow of water and solar intensity at all points of the system.

Acra et al. (1990) observed that with a 95-min exposure to sunlight in Beirut, between 0900 and 1400 h, a 99.9% reduction of the faecal coli forms was achieved with 300 min being required for 99.9% inactivation of the total bacteria. The minimum expose time appears to very with location for reasons related to solar intensity which in turn varies with latitude of geographical location, season (dry or wet), cloud coverage, atmospheric pollution, solar altitude and elevation above sea level (Acra, 1990). Odeyemi (1980) noted that a minimum of 5 h exposure is required for adequate solar disinfection of water in Nigeria. Wegelin et al. (1994) noted that a 5 h exposure of water to mid latitude summer sunshine will corresponds to a dose of 555 W/$m^2$ and will result in a 3 log reduction of *E. coli*.

Acra (1990) recommended that the disinfection method should be applied on small quantities of water only. This is because of the rapid decrease in ultra-violent intensity with increasing water depth and turbidities due to attenuation from its reflection and absorption. High bacterial loads showed a lower sensitivity to solar radiation, when compared with those of low or moderate density (Wegelin et al., 1994).

The advantages of solar disinfection include its non-employment of chemicals, and thus the non-formation of undesirable products associated with chlorination of water. It also carries no risk of overdose (Anghem, 1984). The advantage of using a free natural energy source and requiring few high technological know how with its affordability is worthy of note.

## Others

Others techniques include, boiling which is a safe and effective way of pathogen extinction if carried out properly. The water is boiled for a recommended period of ten minutes. Boiling water might be tedious in terms of time needed to prepare the five and to cool boiled water, also boiling water-using wood is not encourage because of deforestation involved. Cloth filters also used to filter water thus removing microorganisms (Sangodoyin, 1987).

## Conclusions

The overview gave a clearer picture of groundwater as a source of water supply, it characteristics, qualities, pollutions and sources with a purpose of encouraging research activities more in the use of appropriate technology for the treatment of groundwater .area.

The use of appropriate technology for the treatment should be explored the more especially the use of solar radiation.

## REFERENCES


Acra A (1990). Destructive Effect of Sunlight on Bacteria in Oral Rehydration Solution Contaminated with Sewage. Lancet Dec., pp. 1259-1258.

Acra A, Jurdi M, Muallem HK, Raffoul Z (1990). Water Disinfection by Solar Radiation, Assessment and Application. The International Development Research Center.

Anghem K (1984). Drinking water, Treatment agents and Health. J. Royal Society Health, 2(99): 151-159.

Bland J (1980). The village pays its Share. World Health Aug. – Sept., 18: 71.

Buchanan (1983). Ground Water Quality and Quantity Assessment. J. Ground Water. pp. 193-200.

Chapman M (1992). Water Quality Assessments. Chapman and Hall Ltd. WHO, UNEP, UNESCO Church Livingstone, Edinburgh, London and New York, pp. 484-488.

Chilton J (1992). Women and Water. Waterlines J. 2(110): 2-4.

EPA (2005). "Protecting Water Quality from Agricultural Runoff" Fact Sheet No. EPA-841-F-05-001.

Hofkes AK (1981). Water for sustainable development in the 21st century and global perspectives. Water Int., 4(16): 20-25.

Kootapep S, Supot U, Viliurk K, Somai K (1980). Solar Water Disinfection Experiences in Thailand, Proceedings of Workshop on Solar Water Disinfection, by IDRC-MR, 23: 75-81.

Lloyd A, Helmer KA (1991). Impact of Agriculture on water quality. Water int., 3(15): 160-167.

Odeyemi O (1980). Persistence of Pesticides in Water and Public Health Implication. Proceedings of the 1st National Conference on Water Pollution and Pesticide Residue in Foods.

Ogedengbe O (1980). Impact of agricultural practices on water quality. Proceedings of the 1st National Conference on Water Pollution and Pesticide Residue in Foods, pp. 160-167.

Ojo OI (2002). Construction and maintenance of Borehole in Anambra State (PTF sponsored project experience) M.Sc Seminar Report University of Ibadan. Department of Agricultural and Environmental Engineering.

Ojo OI, Ogedengbe K, Ochieng GM (2011). Efficacy of solar water disinfection for well waters: Case study of Ibadan slums, Nigeria. Int. J. Phys. Sci., 6(5): 1059-1067.

Okun K (1983). Preventive Medicine and Public Health. pp. 468-541.

Oluwande P (1983). Guide to tropical environmental health engineering. Nigerian Institute of Social and Economic Research Ibadan (NISER), Ibadan, pp. 141-147.

Osot (2000). Osot Report on PTF Sponsored National Rural Water Supply Schemes.

Park J, Park K (1994). Textbook of preventive and social medicine. Ms Banarsidas bhanot Publishers, 1167, Prem. Nagar, pp. 468-541.

Sangodoyin AY (1987). Lecture note on Advances hydraulics and water resources Department of Agricultural and Environmental Engineering. University of Ibadan, Ibadan.

Sangodoyin AY (1993). Considerations on Contamination of Groundwater by Waste Disposal System in Nigeria Environmental Technology, 14(10): 957-264.

Sangodoyin AY, Agbawhe OM (1991). Environmental Study on Surface and Groundwater Pollutants from Abattoir Effluents. Bioresource Tech., 41 (1992): 193-200.

Sangodoyin AY, Osuji GE (1990). Studies on water use and re-use in the industrial, agricultural and domestic sectors (Western Nigeria), implication for water resources planning. Paper presented at CIGR. Intersection symposium in Nigeria Ilorin, pp 5 – 8 Sept. SODIS News (1997). Editorial nos. I and 10.

Skinner FA, Shecon JM (1997). Aquatic Microbiology. Academic Press London. p. 154.

Tebbutt C (1992). Sustainable Water development: opportunities and Constraints Water Int. 13: 189.

Todd K (1980). Groundwater Hydrology. Published by John Wiley & Sons, New York Chichester, - 2nd Edition.

Wegelin M, Canonica S, Mechsner K, Fleischmann T, Pesare F, Metzler A (1994). Solar Water Disinfection: Scope of the Process and Analysis of Radiation Experiments. J. Water SRT Aqua, 3 (43): 154.

WHO (1971). International drinking standards for drinking water 3rd Edition WHO Geneva, Switzerland.

WHO (1984). Health criteria and other supporting information 101: 2.

WHO (1991). World Health Statistics 4(44): 198.

WHO (1995). Guidelines for drinking water quality. WHO Geneva 2nd Edition (1).