## *Original Research Article*

# Assessing qualities of different Sources of Water for mixing Concrete


## ABSTRACT

**This study investigates the effect of water sources on concrete properties. A mix ratio of 1:1.5:3 with 0.5w/c was used in the concrete mixing. Water from Stream, hand-dug well and borehole sources were used as experimented water with pipe borne water as control. Cubes and beams were cast and tested for compression and flexural strength respectively at 7-day and 28-day curing ages. Chemical and physical properties of the water samples were tested. The results indicate that the chemical impurities of all the water type were within the limits given in GS 175-1:2009 and EN 1008, ASTM C94 and AS 1379. The physical specifications were all satisfactory, except the stream water. The water source had no significant effect on the workability of concrete. Effects of efflorescence were not observed on hardened specimens for any of the water source. Specimens mixed with water from hand-dug well had the highest compressive strength.**



*Keywords: water, concrete, compressive, flexural, strength*


## 1. INTRODUCTION

The use of concrete as a material in construction is very old and till date the most plastic material for constructional works. Beside water, concrete is the most consumed substance with three tones used per person per year in the construction industry. There are many factors that determine the quality of concrete and its strength properties. These include the type of cement used, aggregate quality and grading, the degree of compaction, quality and quantity of water used in concreting, curing method, type of reinforcement used given the sizes, arrangement and spacing [1] and [2].

Water alone as a factor comes with impurities that may interfere with the setting of the cement paste and adversely affect the strength of the concrete. Some solvents in water also cause staining on the surface of concrete as well as lead to corrosion of the reinforcements embedded in the concrete and thereby render the building structure susceptible to decay or eventual failure [1] and [3].

Water for mixing concrete according to [1] must be fit for drinking and good drinking water, according to [4] should be treated. In the developing countries, however, people drink water taken from streams, hand-dug wells and boreholes which most often are not treated. Simply because water from these sources is consumed, builders erroneously presume the sources to be acceptable for mixing concrete. In some arid areas, local drinking water is saline and may contain excessive amounts of chloride, undesirable amount of alkali carbonates and bicarbonates which could all contribute to the alkali-silica reaction [1]. It is not, however, out of place to suggest that some water, not necessarily fit for drinking, could be suitable for concrete production. Water with pH ranging from 6.0 to 8.0 is good for concreting [5]. Natural water that is slightly acidic is harmless, but water containing organic acids may adversely affect the hardening of concrete [1].

The major reason for contractors' failure to use the specified potable water for mixing concrete is the absence or inadequacy of its supply at the project sites. If the report given by [4] that 1.1 billion people in the developing world are without access to safe drinking water is to be considered then one can understand the attitude of builders in the developing world in failing to use treated water for mixing concrete.

Pursuant of good quality, price and time for the works the Traditional Procurement System as practiced in developing countries like Ghana recommends an open and competitive tender for public funded works and one of the requisite responsibilities for a participating contractor in such a tender is usually to visit the site and assess prevailing conditions including the source and quality of water and if unacceptable, suggest solutions through method statements [6] and [7].

Beyond the tenders and the ambitious method statements usually put together by hired experts leading to subsequent award of contracts, most successful firms, especially the local ones, thereafter seem not to have any interests in complying with quality control measures imposed by the contract conditions. According to [8] contractors use any water available to the sites notwithstanding what specifications dictate. Owing to a poor culture of quality control that they have, manifesting in non-compliance with regulations and codes, poor workmanship as well as inadequate supervision, [3] observed that building decay which is caused by water-borne chemical agents, is easily initiated during initial constructional stages and may not be noticed long after handing over and subsequent occupation. Interpreting the procurement act, Act 663 of 2003, [7] stipulated only 6 months as defects liability period and within this period defects such as corrosion of mild steel reinforcements may not be seen for remedy. Thus new buildings in this way may be handed over potentially defective with future useful life potentially shortened.

The aim of this study is to find potential replacement for potable water for concrete production taking into consideration the fact that the item is scarce. This aim has also been considered cognizant of the dangers chemical agents can pose to buildings.

The study has taken a cue from the recommendations made by [9] that water with a total dissolved of less than 6% could be used in the production of concrete with acceptable strength and durability. Other motivations in choosing the objective for this work come from the Utilization of treated effluent water samples, water from lakes, washout water and sea water for concrete production [2] and [10].

This study sought to investigate the physical and chemical parameters of water from different water sources, which are mostly used in the production of concrete in Ghana. Compressive and flexural strengths and workability properties of concrete from these water sources were also investigated. [11] Have studied the effect of Magnesium chloride on ordinary Portland cement concrete. The ordinary Portland cement concrete was produced with MgCl2 dosage of 200, 500, 1000, 1500 and 2000 mg/L and deionised water was used in concrete mix M20and M50. In addition to this, control specimens were prepared with deionized water without MgCl2 for comparison. The compressive and tensile strengths were evaluated for 28 and 90 days. The results show that, as the MgCl2 concentration increases, the compressive strength increases and tensile strengths decrease.

## 2. MATERIAL AND METHODS

### A. Materials

**Cement:** Ordinary Portland cement produced from GHACEM, Ghana, with strength of grade 42R was used for the experiment.

**Aggregates:** The sand was air dry and sieved using BS 5mm sieve to separate any foreign material such as roots, stones etc. that might have adverse effect on the performance of the concrete. In addition, a silt test was performed in accordance with [12] on the sand to ascertain the silt content.
Granite of maximum size of 10mm was used as coarse aggregate

**Water Samples:** Water was taken from the following four water sources: tap as control, stream, hand-dug well and borehole. A Completely Randomized Design with four treatments was used for the study.

### B. Preparation and procedures

**Mixing and casting of concrete**: A basic concrete mix ratio of 1:1.5:3.1 (cement: sand: granite) with w/c ratio of 0.5, with a targeted strength of 30 MPa, used. The mixing of concrete was done using 1m$^3$ hand fed concrete mixer. In all four batches of concrete were cast. For each batch 10 cubes of side 150 mm (5 for compression and 5 for water absorption) and 5 beams of cross section area of 150 x150 mm$^2$ and length 300mm for flexural strength test. The tests were conducted in accordance with [13] for compression for flexural. The concrete specimens were cured in water for 28 days under ambient conditions.

**Water Samples Analyses**

These water samples from the four water sources were taken to laboratory for analyses. The parameters monitored were chloride $Cl^-$, pH, magnesium Mg, iron Fe, copper Cu, nitrate $NO_3^-$, sulphate $SO_4^{2-}$, TDS, zinc Zn, alkalinity salinity, carbonates $CO_3^-$, bicarbonate $HCO_3^-$, fluoride $F^-$ and calcium Ca. The monitored parameters were determined in line with laid down standard of Ghana water quality guideline by Ghana Standard Board [14].

**Concrete Slump Test:** The slump test was performed in accordance with [15] A slump cone was filled in three layers of equal volume. Each layer was rodded 25 times with a tamping rod of length 600mm long and 16mm diameter with a hemispherical tip. The cone was lifted upright after leveling the concrete at the top of cone. The slump cone was then set next to the concrete and the difference in height between the slum cone and the original centre of the specimen was recorded.

**Visual Inspection of Hardened Specimens***:* All the specimens after curing were arranged on a platform and careful observed. The purpose of the observation was to determine the colouration resulting from chemical composition of water samples. The findings were recorded in the next section. A Completely Randomized Design was used for the study

## C. Testing Methods and Procedures

**Compressive Strength test:** This test was in accordance with [16] on Cubes at the 7$^{th}$ and 28$^{th}$ day of curing. The cured cube was placed with the cast faces in contact with the platens of digital compressive testing machine. An incremental load was applied to the cube until failure and the maximum compressive stress recorded.

**Flexural strength test:** The determination of the flexural strength was done using the digital flexural strength machine manufactured by Controls Milano, Italy. The beam was positioned in the machine. The beam was then subjected to incremental loading till failure. The maximum tensile stress was recorded.

### D. Data Analysis

Data collected was subjected to one-way ANOVA using the SPSS software version 22. Means were separated at 5% probability level.

## 3. RESULTS AND DISCUSSION

## A. Chemical and physical Properties

Chemical concentrations of the water samples were within the potable water limits and mixing water specification as per [1], [8], [14],] 17], [18] and [19] standards of mixing water. However, pH of the hand-dug well water sample was 5.9 little lower than the recommend limit of 6.5 and the iron for stream water exceeded the maximum limit by 8.33%.

The normal range of pH for drinking water and concrete is between 6.0 and 8.5 [1]. Hence hand-dug well water with a lower pH value would be corrosive making it unsuitable for reinforced steel bars in concrete.

The four water samples contain harmful elements such as sulphate, alkaline and salt but were far below the maximum limit by standard. Physical Properties of sampled Water are in Table I. The colour, taste and odour of the stream water sample were objectionable to consumer, hence; do not conform to potable water specification. The bad odour might have emanated from the deposition of deleterious materials into the water by the people living around the stream. Based on the physical properties water from the stream is not fit for concrete mixing. Notwithstanding the essential chemical constituent of the stream water it is worth trying to use it for mixing concrete. [20] Reported that the fact that a water source has unpleasant colour or taste or smell does not mean deleterious substances are present.

**Table I: Chemical Parameters of Water Sample**

| **Parameters** | **Stream** | **Bore-hole** | **Hand-dug** | **Tap water** | **(GS 175-3:2009) for ...** |
|---|---|---|---|---|---|
| PH | 6.6 | 6.9 | 5.9 | 6.5 | 6.5 – 8.5 |
| Chloride (mg/l) | 47.0 | 42.0 | 46.0 | 41.0 | 250 |
| Magnesium (mg/l) | 23.0 | 40.0 | 10.0 | 11.0 | 50* |
| Iron (mg/l) | 0.325 | 0.025 | 0.040 | 0.000 | 0.3 |
| Copper (mg/l) | 0.45 | 0.025 | 0.01 | 0.37 | 2.0 |
| Nitrate (mg/l) | 2.4 | 2.1 | 2.2 | 2.2 | 50 |
| Sulphate | 9.0 | 1.0 | 3.0 | 41.0 | 250 |

| | | | | | |
|---|---|---|---|---|---|
| (mg/l) | | | | | |
| TDS (mg/l) | 62.3 | 186.0 | 46.5 | 108.5 | 1000 |
| Zinc (mg/l) | 0.04 | 0.31 | 0.23 | 0.31 | 5.0* |
| Alkalinity (mg/l) | 52.0 | 220.0 | 20.0 | 55.0 | 1500+ |
| Salinity (mg/l) | 124.6 | 372.0 | 93.0 | 217.0 | 1600 - |
| Carbonates (mg/l) | 49.0 | 110.0 | 24.2 | 42.8 | 1000 h |
| Bicarbonates (mg/l) | 2.0 | 40.0 | 6.3 | 7.8 | 1000 h |
| Fluoride (mg/l) | 0.0 | 0.17 | 0.0 | 0.4 | 1.5 |
| Colour (apparent) | 18 | 4 | **5** | **4** | ≤5Hazen units |
| Taste | Ob | N/O | N/O | N/O | N/O |
| Odour | Ob | N/O | N/O | N/O | N/O |

Except pH all Parameters are in mg/L or ppm
*Limits obtained from WHO's potable water specification
+limits obtained from EN 1008 (specification for mixing water)
h limits obtained from [21]
- obtained from [22]
Ob- Objectionable
N/O- Not Objectionable

## B. Compressive Strength of concrete

At the end of 7th and 28th days, cubes from each batch were taking for compressive strength test. The results of the compressive strength of concrete cubes are recorded in Tables II.

The compressive strength tests results for the four water sample are shown in Table 2. The hand-dug well water yielded the highest compressive strength value of 19.41N/mm$^2$ for the 7days curing period and 29.85 for the 28 days with the borehole yielding the lowest strength of 17.76N/mm$^2$ for the 7 days and 27.91N/mm$^2$ for 28-day curing age. The tap water's (control) strength was 18.36N/mm$^2$ for the 7 days curing age; 28.54N/mm$^2$ for the 28 days curing age and that of stream was 18.40N/mm$^2$ and 28.65N/mm$^2$ for 7 and 28 days respectively. The entire specimens for the four water samples increased in strength with increase in age from the 7to the 28 day curing age. In ranking the four water samples in terms of strength, the tap water (control) was ranked third place.

**Table II: Compressive Strength of Concrete made from different water samples.**

| **Water Sample** | **7 Days** | | **28 Days** | |
|---|---|---|---|---|
| | **Mean (N/mm$^2$)** | **Std. Dev.** | **Mean (N/mm$^2$)** | **Std. Dev.** |
| Tap water (control) | 18.36 | 1.12929 | 28.54 | 0.77208 |
| Stream | 18.40 | 2.16648 | 28.65 | 1.57762 |
| Hand-dug well | 19.41 | 1.11499 | 29.85 | 0.74726 |
| Borehole | 17.76 | 0.62642 | 27.91 | 0.89605 |

From Table I the alkalinity of hand-dug well, stream and tap (control) water was lower than the borehole sample. This implies that the hydroxide product of the borehole sample concrete would increase, due to the presence of alkaline in the water; therefore delaying hydration hence, low compressive strength. The TDS concentration of hand-dug water is the least. This might have caused less interference with cement active ingredients accounting higher compressive strength, relatively, the more the TDS concentration the lesser the strength of concrete. This result is in line with the study of [9] on alternative water sources where the experimented samples compressive strength performed better than the control. On the contrary, the study of [8] on Ogunpa stream in Nigeria, the control (tap water) performed better than the experimented. The conflicting results in these studies might be due to different chemical concentration of those water samples. While, the impurities in the samples of [8] study were beyond the stipulated limits by standard, hence performing poorly, impurities in the samples of [9] were within the accepted limit.

Previous studies stipulates that if the compressive strength is up to 90 percent of the control specimen then the source of water may be accepted for concrete production [17], [18], [19]and [23]. The compressive strength of concrete cubes mixed with stream, hand-dug well and borehole were 100.38%, 104.59% and 97.42% respectively over the control cubes, indicating that all the experimented water are good for mixing concrete. One factor ANOVA test at a significance level of 5% was also conducted as shown in Table III to test if the difference in group means is attributed to chance or error. The F-value = 1.745 shows low variability between the different water sources than variability within each group. The Significance level was 0.235, that is F (3, 8) = 1.745; P>0.05. This indicates that the water samples have no significance influence on the strength of concrete. This result was in line with [9] who in similar study, concluded that water quality does not seriously affect the performance of concrete provided the water lies within the specified limits by standard.

**Table III: ANOVA Summary of the Compressive Strength of the Four Water Samples**

| Strength | Sum of squres | Df | Mean squres | F | Sig. |
|---|---|---|---|---|---|
| Between groups | 5.9 | 3 | 1.9 | 1.745 | .235 |
| Within groups | 8.9 | 8 | 1.1 | | |
| Total | 14.8 | 11 | | | |

### C. Strength versus Alkalinity and TDS

The relative variation in strength among water samples was partly attributed to the concentration of Alkaline and TDS content in the samples. From Table IV alkalinity and TDS concentration resulted in a corresponding high strength. It can be inferred that there exists a negative correlation between concrete strength and alkaline and TDS. From this a model was developed using the SPSS as shown:

$R^2$ = 0.872 Adjusted $R^2$ = 0.72

where Cs = Concrete Strength

The Adjusted $R^2$ value 0.72 indicates that 72 % of variation in strength can be explained by the alkaline and TDS content of the water sample. The Table IV is the constant for determining concrete strength, the negative coefficient of alkaline and TDS imply if alkaline and TDS content are increased by one unit each Cs will on the average decrease by 0.11 and 0.005 respectively.

**Table IV: Strength versus Alkalinity and TDS**

| Concrete's Strength (Cs) $Nmm^{-2}$ | Water Parameter (ppm) | |
|---|---|---|
| | Alkalinity | TDS |
| 29.85 | 20.0 | 46.5 |
| 28.65 | 52.0 | 62.3 |
| 28.54 | 55.0 | 108.5 |
| 27.91 | 220.0 | 186.0 |

### D. Flexural Strength

The results of the Flexural strength of concrete samples in the study are shown in Table V. The Flexural strength followed the pattern of the compressive strength. The hand-dug well specimen recorded the highest strength value of 4.46N/mm$^2$ whereas the borehole specimen recorded the least strength value of 4.18N/mm$^2$ and that of stream and tap (control) was 4.32N/mm$^2$ and 4.27N/mm$^2$ respectively. In comparing the two strengths (compressive and flexural), there exists a relationship between the two; hence the same factors that influenced the variations in compressive strength also influenced the flexural strength. In this study, the relative strength of the four water samples: tap water (control), stream water, hand-dug well and borehole was 16.72%, 15%, 14.94% and 14.97% respectively. This result was also in line with Bureau of Indian Standard (BIS) and Indian Roads Congress (IRC).

**Table V: Flexural Strength versus Water Sample**

| Water Sample | N | 28- Day Curing Age | |
|---|---|---|---|
| | | Mean ($N/mm^2$) | Std. Dev. |
| Tap Water (control) | 3 | 4.27 | 0.48539 |
| Stream | 3 | 4.32 | 0.71141 |
| Hand-dug well | 3 | 4.46 | 0.56400 |
| Borehole | 3 | 4.18 | 0.59506 |

## E. Visual Inspection of Hardened Specimens

Visual inspection on specimens was conducted to determine any physical changes in the specimens. Generally, there was not much difference in the physical appearance of specimens made from tap water (control), hand-dug well and borehole in terms of colour, they were normal grey colour. However, specimen produced from stream water was seen to be yellowish. The yellowish colour found on the stream specimen resulted from the colour of the water. Signs of efflorescence were not noticed on any of the specimens. This may be attributed to the fact that the salinity related to elements in all the four water samples were at minimal level as against the reference standard.

# 4. CONCLUSION

## A. Conclusions

The results of the studies support the conclusions that water source may not be good for drinking due to its odour, taste and colour but may be good for making concrete which may equally compete in strength with potable water. Water samples whose parameters are below the maximum limit by drinking and mixing water specifications do not show a sign of staining i.e. efflorescence. The water samples showed no significant effect on compressive and flexural strength.

## B. Recommendation

Based on the results of this study, the following recommendations would be useful:

1. Stream water which is coloured is not recommended for facing work.
2. To do further study about various durability aspects such as long term volume stability.
3. To reduce pressure on potable water government should make legislation to accept the use of other sources of water different from potable water.
4. Other sources of water to be accepted should first be assessed through their use in concrete samples which subsequently should be crushed to see if their strengths amount to 90% strength of concrete cast using potable water.
5. Where stream water is to be used, tests have to be conducted every time the water is taken since stream water quality keeps changing depending on the different prevailing temperatures and given the fact that discharges such as municipal wastes which are likely to be made into the rivers also bring about changes in the chemistry of the water [24].

# REFERENCES

[1] Neville AM. Properties of Concrete 4thed.,ELBS Longman. 1996;844pp
[2] Su N, Miao B, Liu FS. 'Effect of wash water and underground water on properties of concrete', Cement and Concrete Research32, 2002; pp 777–782
[3] Emmit S. Architectural Technology. Published by Blackwell Science Ltd. Oxford, U.K 2002;pp 192-195
[4] WHO- UNICEF report (2004)
[5] McCoy WJ. Mixing and curing water for concrete, ASTM, Special Technical Publication, 1978; 169:765-773

[6] Cooke B. Contract Planning and Contractual Procedures (2nd Edition). MacMillan Education Ltd. Houndmills, Basingstoke,Hampshire. 1990; pp 8-27
[7] Acquaye JA. Guide to Practice of Procedures in Public Procurement of works. Roystack Style Publications, Accra, Ghana. 2011; pp 10-15
[8] Gbenga MA. Water Quality effect on Concrete Compressive Strength; Ogunpa stream water case study, Civil Engineering Horizon online Journal 2009;, January 1, 2014. (horizon.webinfolist.com)
[9] McCarthy LM. Analysis of alternative water sources for use in the manufacture of concrete. Maters thesis, Queensland University of Technology –School of Physical and Chemistry Sciences (2010), September 11, 2013 (eprints.qut.edu.au/37648/1/Leigh_McCarthy_Thesis.pdf)
[10] Sandrolini F, Franzoni E Waste wash water recycling in ready-mix concrete plants. Cement and Concrete Research, 2001; 31:485-489
[11] Reddy VV Ramana NV, Gnaneswar K, Sashidhar C. Effect of magnesium chloride (MgCl2) on ordinary Portland cement concrete‖ Indian Journal of Science and Technology. 2011
[12] BS882:1992, Method of determining silt content from aggregate, British Standard Institute, London

[13] BS 1881: Part 127: Method for determination of water absorption of concrete, British Standard Institute, London. 1990
[14] BS 1881: Part 116: Method for determination of compressive strength of concrete, British Standard Institute, London. 1983
[15] BS 1881: Part 108: Method for making for test cubes from fresh concrete, British Standard Institute, London;1983
[16] GS 175-1: Water Quality- Specification for Drinking Water, Ghana Standard Board, 3rd ed ISO 7890-1:1986- Water quality, International Organisation for Standardization; 2009.
[17] EN 1008 Mixing water for concrete – specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
[18] ASTM C1602-06, Standard Specification for Mixing Water Used in the Production of Concrete
[19] AS 1379 Specification and supply of concrete Standards Australia
[20] Neville AM, Brooks JJ. Concrete Technology, 2nd ed., Pearson Education Ltd, Harlow. 2010; 441pp
[21] Cement Concrete and Aggregate Australia. Use of Recycled water in concrete production. 2007;May 12, 2013; www.concrete.net.au/publications/pdf/Recycled Water.pdf
[22] Akinsola OE, Fatokun AO, Ogunsanm OE. i.Investigation of Salinity Effect on Compressive Strength of Reinforced Concrete. Journal of Sustainable Development; 2012; Vol. 5, No. 6; ISSN 1913-9063 E-ISSN 1913-9071 Published by Canadian Center of Science and Education
[23] Patil GK, Jamkar SS, Sadgir PA. Effects of chemicals as impurities in mixing water on properties of concrete. International Journal of Research in Chemistry and Environment, 2011; vol.1, ISSN 2248-9649, April, 20, 2014 (www.ijrce.org)
[24] Akpen GD, Ekanem EJ Agunwamba JC . The Effects of Sewage Effluent discharge on the water quality of Wupa river in Abuja, Nigeria. Journal of Science and Technology. 2016: 36(2): 86-95