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Assessing the Performance of Concrete Mixed with Different Water Sources within Small Scale Mining Catchment Areas in Ghana

Peter P. K. Yalley[1], Emmanuel Appiah-Kubi[1*], Emmanuel Osei-Tweneboah[1] and Charles K. Kankam[2]

[1]Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development,
P.O.Box 1277, Kumasi, Ghana.
[2]Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. Author PPKY and EOT designed the study, wrote the protocol and wrote the first draft of the manuscript. Author EAK managed the analyses of the study and the literature searches. Author CK performed the statistical analysis and reviewed the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The performance of concrete samples mixed with different water sources, namely: tap water, river, borehole and hand-dug well from small scale mining catchment areas (known as "galamsey" in Ghana) was assessed. Concrete in the "galamsey" areas are being produced with these water sources contaminated by the mining activities. The objective of the study was to assess the performance of concrete mixed and cured with the different water sources. Parameters assessed included compressive and flexural strength, Sulphate attack and Scanning Electron Microscopy (SEM) Analysis. Concrete mixing and casting were in accordance with BS EN 12390-2:2019 while compressive and flexural strength tests were in conformity to BS EN 12390-3:2019 and BS EN 12390-5:2019 respectively. Water parameters tests were conducted in accordance with GS 175-1:2009. Sulphate attack test was conducted based on ASTM C1012:2018. The results indicate that the compressive strength of concrete from all the water sources (river, hand-dug well and

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**Corresponding author: Email: eakubi@aamusted.edu.gh;*

borehole) was about 90% and 70% of the control (tap water) specimens at the 28th and 180th days of curing respectively. It was noted that the concrete produced from the three water sources (borehole, hand-dug well and river) performed poorly against sulphate attack i.e. lost about 35%, 34% and 38% respectively of their compressive strength after 180 days of immersion in $MgSO_4$ solution. Concrete mixed with the river and hand dug well water had lower alkalinity with pH values of 6.5 and 8 respectively. The morphological analyses at different magnifications showed deep and persistent cracks within the concrete mixed with the contaminated water. This study recommends that water from any of the water sources in the "galamsey" areas of Ghana should be treated before using for structural concrete and long term usage.

Keywords: Concrete; performance; water sources; mining areas.

1. INTRODUCTION

Water for mixing concrete must be fit for drinking and should be as good as treated water [1]. In developing countries, people drink water sourced from rivers, boreholes and hand-dug wells which most often are not treated. According to Yalley et al. [2], water from various sources is consumed, hence builders presume these sources to be acceptable for mixing concrete. Water is one of the components for concrete production and constitutes 14% to 21% of the volume of concrete. The activities of small scale mining known locally in Ghana as "galamsey" are normally done alongside water bodies. Mercury, cadmium, lead and other poisonous chemicals, are used to recover gold from the ore, and in the process some spillages occur resulting in drainage of these into water. The rivers, hand-dug wells and boreholes in villages in Ghana serve as sources of drinking water and are also used for the mixing of concrete. The "galamsey" activities are therefore affecting the quality and availability of water resources in the mining catchment areas. In Ghana and other developing countries, construction contract documents specify the use of potable water in concrete building construction; however, contractors tend to use water available in the construction area, without any proper assessment of the quality of the water used [3]. The lack of portable water and/or its inadequacy on project sites has led to the failure of contractors using the specified potable water for mixing concrete. WHO-UNICEF [4] report indicated that 1.1 billion people in the developing world are without access to safe drinking water. This could be the reason why builders in the developing countries are failing to use treated water for mixing concrete. Water for mixing and curing of concrete in small scale mining catchment areas are from water sources in those areas. The question that comes to mind is the potability of the water from various water sources in the "galamsey" areas which are used for mixing and curing of concrete for construction in the catchment areas.

Various studies conducted on the water quality of rivers in small scale mining catchment areas in Ghana, found that the waters are lightly to moderately acidic due to the presence of heavy metals like iron, lead and manganese in the water, as a result of the activities of small scale mining [5,6]. Al-Hassan and Amoako [7]; Aryee et al. [8] studies on environmental and security aspects of contemporary small scale mining in Ghana, revealed that the operations of small-scale mining, have generated concomitant environmental problems. Their studies revealed that there was extensive pollution of streams and rivers with silt, mercury, cadmium, cyanide and other chemicals, thereby rendering water unsafe for drinking.

Independent studies by Dorleku et al. [9]; Donkor et al. [10]; Kpan et al. [11]; Kwaansa-Ansah et al. [12]; Duncan et al. [13] and Donkor et al. [14] on physico-chemical and heavy metal contaminations of rivers by small-scale mining in Ghana, also revealed that there was higher concentration of heavy metals in river sources in the small-scale mining catchment areas. Studies conducted on chemical analysis of water from water sources from small-scale mining catchment areas in South Africa [15] and Croatia [16], showed higher concentration of heavy metals namely: lead, cadmium, copper, and zinc in rivers in small-scale mining catchment areas. They attributed the higher concentration of these heavy metals to improper disposal of mine tailings. Almost all the studies on water sources in small-scale mining catchment areas concentrated on environmental issues and water quality for drinking and other domestic uses but disregarded the effect of the water on concrete and other building materials. The aim of this study was to assess the quality of the different sources of water (river, hand-dug well, borehole) in the small scale mining areas, and determine the influence of the water on the properties of the concrete produced with the water sources. This study therefore focuses on the effect of water from the various water sources in the small scale mining catchment areas on the quality of concrete.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Cement

Ordinary Portland cement produced by Ghana Cement (GHACEM) with a strength grade of 32R conforming to BS EN 197-1 [17] was used for the concrete mixes.

2.1.2 Water

Water obtained from the Ghana Water Company which conformed to the requirements of BS EN 1008 [18] was used for the production of control samples. Other four water sources were: river, hand-dug well and borehole all from illegal small-scale mining catchment areas (Galamsey areas). Water from the river source was sampled from two rivers in the catchment area, namely, Annum and Owere. Water from the hand-dug well and borehole was sampled from 10 communities in the “galamsey” area.

2.1.3 Aggregates

Natural quartz sand with a fineness modulus of 3.1 and a gradation of 0.16 - 5 mm and granite gravel with a gradation of 10 - 12 mm which conformed to BS EN 12620 [19] were used for the production of the concrete.

2.2 Concrete Specimens Preparation

Based on targeted strength of 30 N/mm^2, a mix ratio of 1:1.5:3 (cement: sand: crushed granite rock) with w/c ratio of 0.5, was used. The concrete was mixed using a 1 m^3 concrete mixer. In all, four batches of concrete were cast with each batch mixed with a different water source. For each batch, 84 cubes of size 100 mm and 12 beams with cross section area of 100mm square and length 500 mm were cast. The specimens were prepared and cured in accordance with BS EN 12390-2 [20]. Table 1 indicates the test conducted and the number of specimens tested. The specimens were cured by water immersion, for up to 180 days, with tests conducted on the 7th, 28th, 56th, 90th and 180th day depending on the type of test.

2.2.1 Visual inspection of hardened specimens

All the specimens were carefully observed after curing. The purpose of the observation was to identify any colouration resulting from any reaction due to the chemical composition of the water used in preparing the concrete.

2.3 Tests and Procedures

2.3.1 Water samples analysis

The water samples from tap, hand-dug well, borehole and rivers, in the “galamsey” areas were taken to the laboratory for analysis. The parameters monitored were pH; total dissolved solids (TDS); total solute solvent (TSS); alkalinity (MgOH); salinity (MgCl); the presence of magnesium (Mg), chloride (Cl^-), iron (Fe), copper (Cu), nitrate (NO_3), sulphate (SO_4), zinc (Zn), carbonates (CO_3), bicarbonate (HCO_3-), fluoride (F), calcium (Ca), lead (Pb), mercury (Hg), cadmium (Cd). The parameters were determined in accordance with the requirements of GS 175-1 [21].

2.3.2 Concrete slump test

The slump test was performed in accordance with BS EN 12350-2 [22].

2.3.3 Compressive strength test

The test was conducted in accordance with BS EN 12390-3 [23] on cubes at the 7th and 28th days curing. A compressive testing machine (Fig. 1) was used for the testing. An incremental load was applied at a loading rate of 5 kN/s (5 mm/min) to every cube until failure and the maximum compressive stress recorded.

2.3.4 Flexural strength test

The flexural strength test was conducted using a digital flexural strength testing machine manufactured by Controls Milano, Italy, as shown in Fig. 2. With a central point loading setup, the beam was subjected to incremental loading at a loading rate of 0.20 kN/s until failure, in accordance with BS EN 12390-5 [24]. The maximum tensile stress was recorded.

Table 1. Concrete samples tested

Type of specimen	Property (Test Conducted)	Specimen number	Test age (days)	Size (mm)
Cubes	Compressive strength	36	7, 28 &180	100x100x100
Cubes	Sulphate attack	48	28, 56, 90 & 180	100x100x100
Cubes	SEM Analysis	-	180	100x100x100
Prism	Flexural strength	12	28	100x100x500

Fig. 1. Compressive strength test setup

Fig. 2. Concrete beam under flexural strength test

2.3.5 Sulphate attack on concrete

The sulphate attack test was conducted by immersing concrete specimens after the 28th day curing in water as shown in Fig. 3. The test followed ASTM C1012 [25]. The test was conducted in a laboratory with a relative humidity of 80% and temperature of 23°C ± 5°C. The concrete specimens were further cured in a water tank containing 5% magnesium sulphate for 28, 56, 90 and 180 days. The pH level of the sulphate solution was monitored. The sulphate solution was replaced whenever the pH value exceeded 9.5. The degree of sulphate attack was evaluated by measuring the compressive strength and weight losses of the specimens at the 28th, 56th, 90th and 180th days of immersion in the sulphate solution.

2.3.6 Alkalinity measurement on concrete

Tests were carried out on specimens at the 28th day of water curing. The pieces of tested specimens were again broken into small pieces using a hammer and a ball mill and then powdered. Twenty grams of each of the powdered samples, was put into 100 ml distilled water (Fig. 4). The aqueous solution was allowed to stand for 72 hours to enable more free lime of hydrated cement paste to dissolve in the water. The pH of the aqueous solution was measured by a pH meter. The pH value was used to determine the level of alkalinity.

2.3.7 Scanning Electron microscopy (SEM) analysis and energy- dispersive x-ray spectroscope (edx) test on concrete specimen

Phenom Prox S-3400N Scanning electron microscope (SEM) was used to take images of the concrete samples as shown in Fig. 5. A concrete prism after curing for 28 days was cut into cubes of size 10mm. The specimen was subjected to gold sputtering to make it conductive. The testing procedures were performed according to ISO/TS 24597 [26].

3. RESULTS AND DISCUSSION

3.1 Chemical and Physical Properties of Water Samples

Table 2 presents the average values of the results obtained from the laboratory analysis. The average pH values of the water from the hand-dug well, borehole and the rivers were below the WHO recommended lower limit of 6.0 for water fit for mixing concrete [1]. The temperature of the water from the river sources in the “galamsey” area was 30.4°C which was slightly higher than room temperature fit for concrete mixing. The water from the rivers in the "galamsey" area was likely to cause corrosion in the steel reinforcement bars in the concrete if used to mix and cure concrete. Elevated temperatures may result in long-term strength loss of concrete [27].

The average iron (Fe) content in the water from the three sources also exceeded the maximum limit of WHO by between 465% and 853%. Ferric iron as impurities in mixing water has the tendency to reduce the strength of concrete [28].

The average level of TSS recorded for the water from the bore-holes, hand-dug wells and rivers, exceeded the recommended limit of 50 ppm by 13%, 22% and 37% respectively. This could be due to dissolved materials related to the activities of the miners. The amount of TDS in all the four water sources was lower than the WHO limit. The presence of cadmium in all the water sources is within the recommended level of WHO. Lead and mercury in the water, except the tap water, was over 4000% higher than the WHO recommended values. The early age strength of the concrete mixed with such water could be reduced due to the high content of lead and mercury [29]. The turbidity of water from the hand-dug wells, bore holes and rivers was 59%, 58% and 157% respectively higher than the WHO limit. The higher turbidity in the water, except the tap water, could retard the development of early age strength thereby increasing the setting time of concrete [1]. The alkalinity of the tap water was lower than the other three water sources. This could imply that the hydration process of the concrete mixed with the water sources, other than the tap water, would delay due to the presence of excess alkaline in the water.

Fig. 3. Cubes in $MgSO_4$ solution

Fig. 4. Measure of alkalinity

Fig. 5. SEM/ EDX set Up

3.2 Visual Inspection of Hardened Concrete Specimens

Visual inspection was conducted on the specimens to observe any strange colouration or appearance. Specimens made from tap water (control), hand-dug wells and boreholes did not show any strange appearance in terms of colour; they had the normal grey colour of a good concrete. However, specimens produced with the water from rivers were seen to be yellowish. The yellowish colour found on the specimens could be attributed to the colour of the rivers themselves. Signs of efflorescence were however not noticed on any of the specimens. The same observations were made by Yalley et al. (2019). This could be attributed to the fact that the magnesium chloride (MgCl) content in the various water sources was relatively low compared to the reference standard.

3.3 Compressive Strength

The results in Table 3 indicate that concrete mixed with water from the water sources in the “galamsey” areas had their early compressive strength lowered by 21%, 18% and 13% for water from the river, hand-dug well and borehole respectively compared to the controlled sample (tap water). The loss of early age strength could be attributed to the high turbidity and the presence of mercury and lead in the water as a result of the "galamsey" activities [29]. The presence of high turbidity, mercury and lead could have increased the setting time of concrete, thereby retarding the development of early age strength. Also the high alkalinity in the water sources, except, the tap water, might have increased the hydration product of the concrete, therefore delaying hydration and reducing the early age strength of the concrete [30].

On the 28th day of curing, the concrete mixed and cured with water from the "galamsey" areas gained 35% of their compressive strengths, while the increase in the compressive strength of concrete mixed with the tap water was 27%. The compressive strength of concrete mixed and cured with tap water was, however, 20% higher than that of the concrete mixed and cured with water from the river. The TDS concentration of water samples from the rivers was more than that of the tap water. This might have caused more interference with cement active ingredients accounting for the lower compressive strength. The higher the TDS values the lower the compressive strength of the concrete. This result corroborates the study of Gbenga [3] in Nigeria that showed that tap water performed better than the experimented water source (Ogunpa stream). The compressive strength for water samples from the hand dug wells and boreholes at 28 days curing period was up to 90 percent of the control specimen, hence the source of water may be accepted for concrete production where the early age strength may not be significant. However, at a later curing age of 56 days, the compressive strength of the concrete made from all the water sources, besides the tap water, slightly decreased. This implies that the water sources from the "galamsey" areas might not be suitable for concrete for long term use and for elements of structural importance.

One factor ANOVA test at a significance level of 5% was also conducted as shown in Table 4 to test if the difference in group means is attributed to chance or error. The F-value (F= 4.756) shows high variability between the different water sources other than variability within each group. The Significance level was 0.001, that is F (4, 8) =4.75; (P = .05). This indicates that the water samples have significant influence on the strength of concrete.

3.4 Flexural Strength

Fig. 6 illustrates the results of the flexural strength of the concrete specimens. The results followed the pattern of the compressive strength results. The beam cast with tap water recorded the highest strength value of 4.46 N/mm^2 whereas that of the borehole recorded the least strength value of 4.18 N/mm^2. The flexural strength values of specimens mixed with water from the rivers and hand-dug well were 4.32 N/mm^2 and 4.27 N/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 could be said to have also influenced the flexural strength.

3.5 Sulphate Attack

Sulphate attack on ordinary Portland cement matrix is generally characterized by the development of sulphate ions during the cement hydration process, which causes expansion, cracking and spalling as well as loss of mass and strength. The sulphate attack was measured by percentage loss of weight and compressive strength.

3.5.1 Loss in compressive strength

Results from Fig. 7 indicate the loss of compressive strength of concrete after 28 days' immersion in 5% of magnesium sulphate ($MgSO_4$). The compressive strength loss was 23%, 26%, 25.5% and 30% for concrete mixed and cured with water from tap, bore hole, hand dug well and river respectively. After 180 days of immersion in $MgSO_4$ solution, the concrete with water from the tap, borehole, hand-dug well and river lost about 32%, 35%, 34% and 38% respectively of their compressive strength. The loss of compressive strength was highest in the concrete mixed with water from the rivers. This could be ascribed to the higher presence of TSS and TDS which might have been dissolved by the $MgSO_4$ solution leaving voids in the concrete, hence the higher loss of compressive strength.

3.5.2 Loss of weight

From Table 5, the results showed the changes in weight concrete samples mixed and cured with sources of water from the "galamsey" areas, after immersion in 5% magnesium sulphate ($MgSO_4$) solution. The pH value after immersion in 5% magnesium sulphate ($MgSO_4$) solution was found to range from 5.6 to 6.0 for the contaminated water sources of rivers, hand-dug wells and borehole, whereas the tap water had a value of 6.6 (approximately neutral). The percentage weight loss after 180 days of curing was 20% for the control mix. Concrete mixed and cured with water from the rivers had the greatest weight loss of 35%. The weight losses for concrete mixed and cured with boreholes and hand dug well water were 24.5% and 25.5% respectively. The rivers where most of the waste water from "galamsey" activities are disposed-off contain higher percentage of TDS, TSS, turbidity and mercury (Hg), which might have been destroyed by the $MgSO_4$, hence reducing the weight of the concrete specimens and eventually the compressive strengths.

3.5.3 Regression analysis: Loss in Compressive Strength (LCS) versus Turbidity, TSS, TDS

$$\text{LCS} = 27.01 + 0.1330\ \text{Turbidity} + 0.09969\ \text{TSS} + 0.003297\ \text{TDS} \qquad \text{Eq. 1}$$

From the regression analysis about 92% of the loss in compressive strength (LCS) of concrete specimens in $MgSO_4$ solution, could be explained by the presence of turbidity, TDS and TSS in the water samples. The water sample from the rivers in the "galamsey" areas had the highest turbidity, TSS and TDS, therefore making concrete specimens mixed and cured with water from the rivers lost more weight and compressive strength. Equation1 indicates the relationship between LCS, TDS and TSS.

3.6 Measurement of Alkalinity of Concrete

The results of the pH values of the concrete samples as shown in Fig. 8 indicated that the concrete samples mixed with tap water and borehole were alkaline with PH values of 9 and 11 respectively. On the other hand, concrete samples mixed with the rivers and hand dug wells had pH values 6.5 and 8 respectively, which fell below the range of alkalinity of between 9 and 12. The alkalinity in the concrete specimens mixed with water from the rivers and hand dug wells was not adequately high enough to protect the steel reinforcement bars from corrosion.

3.7 SEM and EDS Analysis

The concrete samples prepared with water from tap, hand dug well, borehole and river had the weight concentration of mercury values of about 2.47kg, 96kg, 65kg and 99kg respectively. The specimens made from the river and the hand-dug well showed heavy presence of mercury in the concrete sample as indicated in Table 6 and demonstrated by the EDS images in Fig. 9.

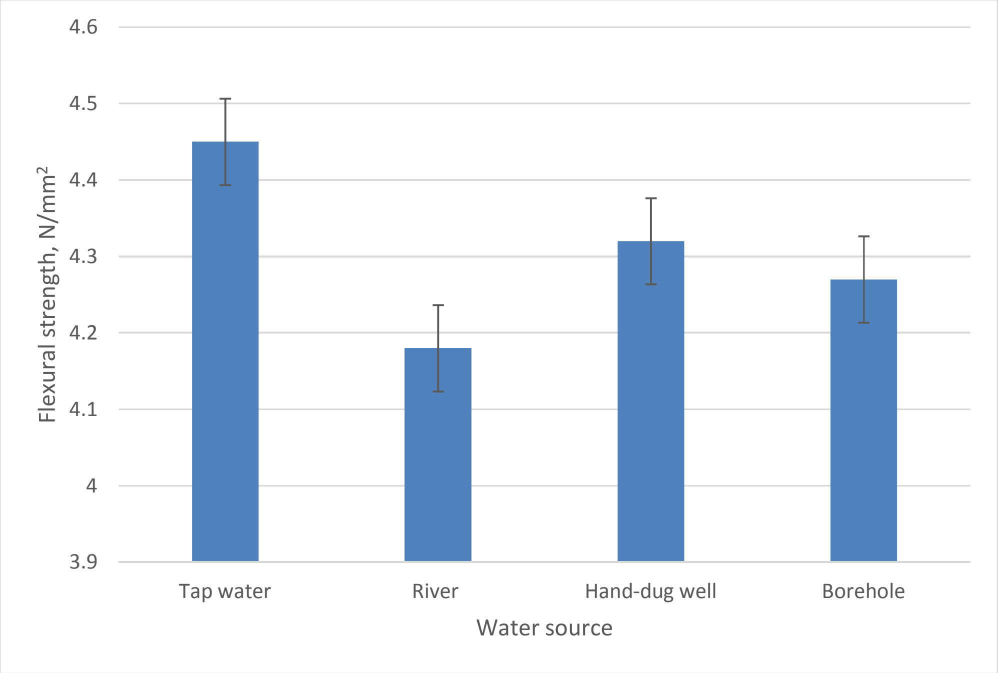


Fig. 6. Flexural strength of concrete specimens after 28th day curing

Table 2. Chemical parameters of water sources

Water parameters	Tap water	Hand dug wells	Bore holes	Rivers	WHO Range
PH	6.6	5.9	6. 0	5.6	**6.5-8.5**
Total Solute Solvent (TSS) (mg/l)	45	61.25	56.74	68.50	**50**
Temperature	23	28.403	27.583	30.377	**22-29**
Total Dissolved Solids (TDS) (mg/l)	108.5	277.633	266.533	693.300	**1000**
Conductivity	101	114.00	190.00	148.10	
Turbidity	1.10	7.45	7.90	12.83	**5**
Alkalinity	55.0	201.20	260.00	210.32	**1500**
Manganese (mg/l)	11	10	40	23	**50**
Chloride (mg/l)	43	18	23.10	12.36	**250**
Cadmium (Cd) (mg/l)	0.00	0.003	0.001	0.003	**0.003**
Lead (Pb) (mg/l)	0.00	0.443	0.453	0.540	**0.01**
Mercury (Hg) (mg/l)	0.00	3.227	1.670	3.871	**0.005**
Iron (Fe) (mg/l)	0.00	2.187	1.695	2.860	**0.3**
App. Colour	4	9.707	9.000	18.233	**15**
Odour		Obj	Obj	Obj	
Taste		Obj	Obj	Obj	

Obj = Objectionable

Table 3. Compressive strength of concrete from the four water sources

Water Source	7 days curing		28 days curing		180 days curing	
	Mean (N/mm^2)	Std. Dev.	Mean (N/mm^2)	Std. Dev.	Mean (N/mm^2)	Std. Dev.
Tap water	22.36	1.13	30.54	0.77	33.00	0.71
River	17.76	2.12	27.65	1.63	22.54	1.53
Hand-dug well	18.41	1.11	28.40	0.75	23.50	0.84
Borehole	19.40	0.53	29.85	0.89	24.04	0.76

Table 4. ANOVA summary of the compressive strength of concrete from the four water sources

Compressive strengths	Sum of squares	Df	Mean squares	F	Sig.
Between groups	6.8	4	3.7	4.756	.001
Within groups	9.9	8	2.2		
Total	16.7	12			

Table 5. Percentage loss of weight after immersion in $MgSO_4$

Concrete specimens	Immersion period (days)			
	28	**56**	**90**	**180**
Tap water	5.6	13.5	19.0	20
River	20.4	28.0	32.0	35.0
Hand-dug well	10.4	16.2	20.6	25.5
Borehole	8.4	18.2	20.3	24.5

R-Sq = 94.5% *R-Sq(adj) = 91.8%* *S = 0.016522*

Table 6. Chemical presence in the concrete samples

Element Symbol	Tap water		Hand-dug well		Bore hole		Rivers	
	Atomic Conc.	**Weight Conc.**	**Atomic Conc.**	**Weight Conc.**	**Atomic Conc.**	**Weight Conc.**	**Atomic Conc.**	**Weight Conc.**
Hg	2.20	2.47	66.72	95.69	50.52	65.27	91.35	98.87
O	67.54	49.92	21.38	2.45	34.52	16.32	3.96	0.34
Ca	7.25	13.43	3.03	0.87	7.23	12.78		
C			6.83	0.59	5.36	2.09		
Si	13.88	18.02	1.40	0.28	1.7	2.76	2.62	0.40
Al	4.64	5.78	0.64	0.12	0.86	0.15	0.73	0.11
K	1.54	2.78					1.34	0.28
Fe	2.95	7.60				3.64		
Mg	2.20	2.47						

Source: Field data, July 2020

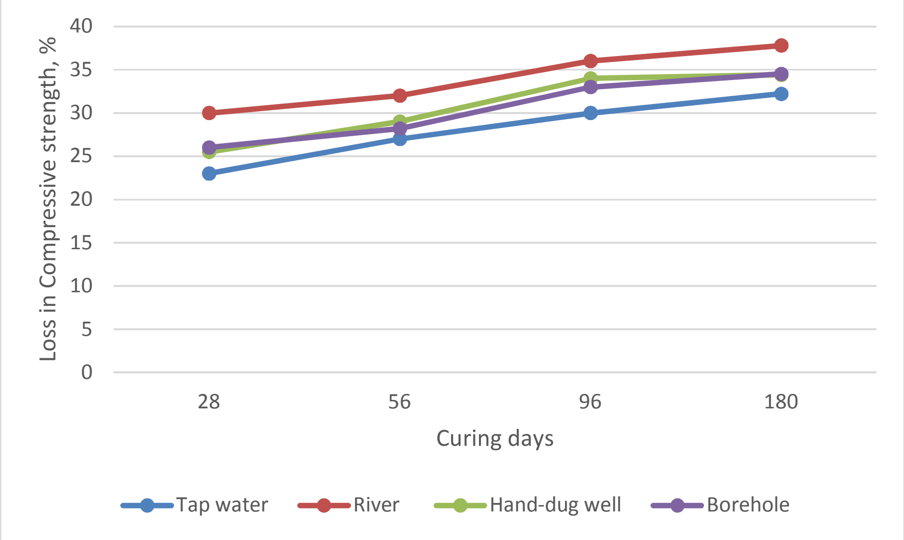


Fig. 7. Loss in compressive strength after immersion in MgSo4

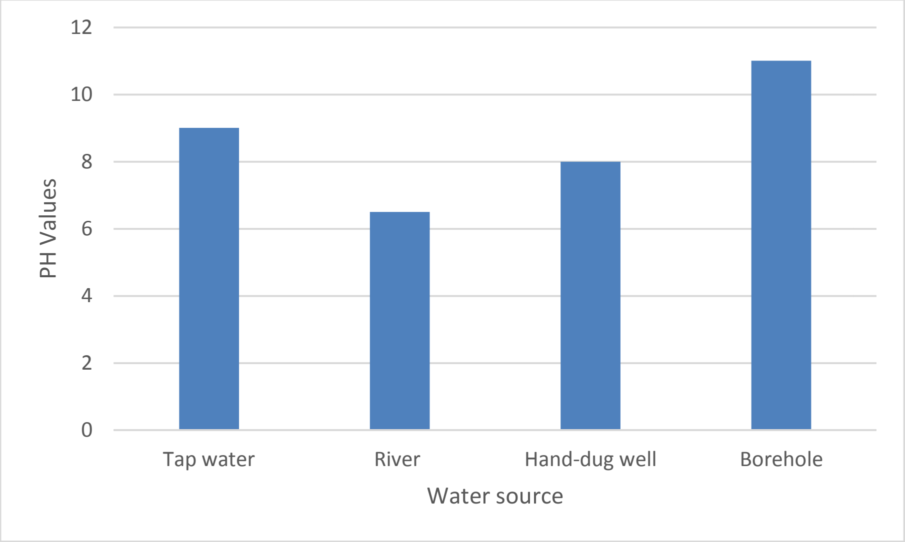
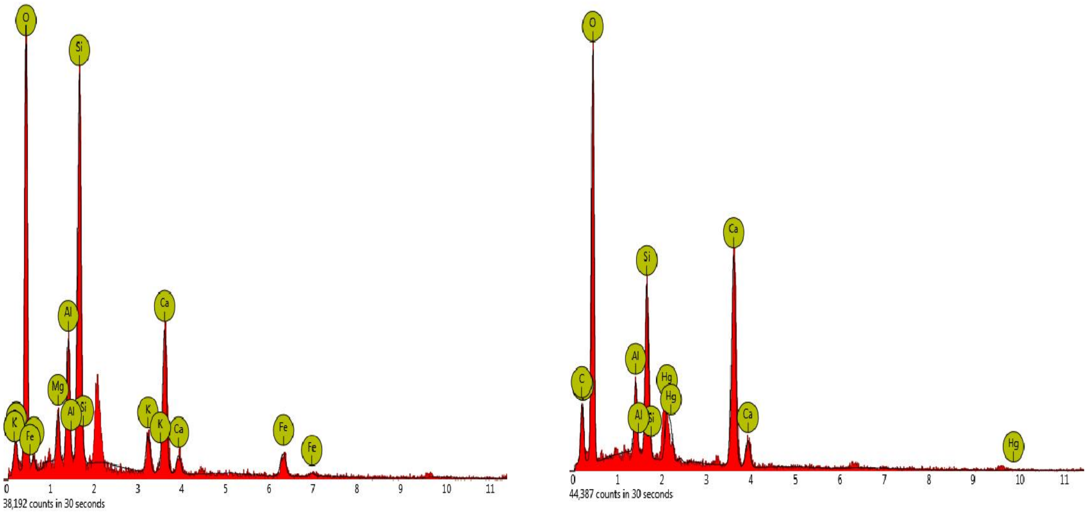
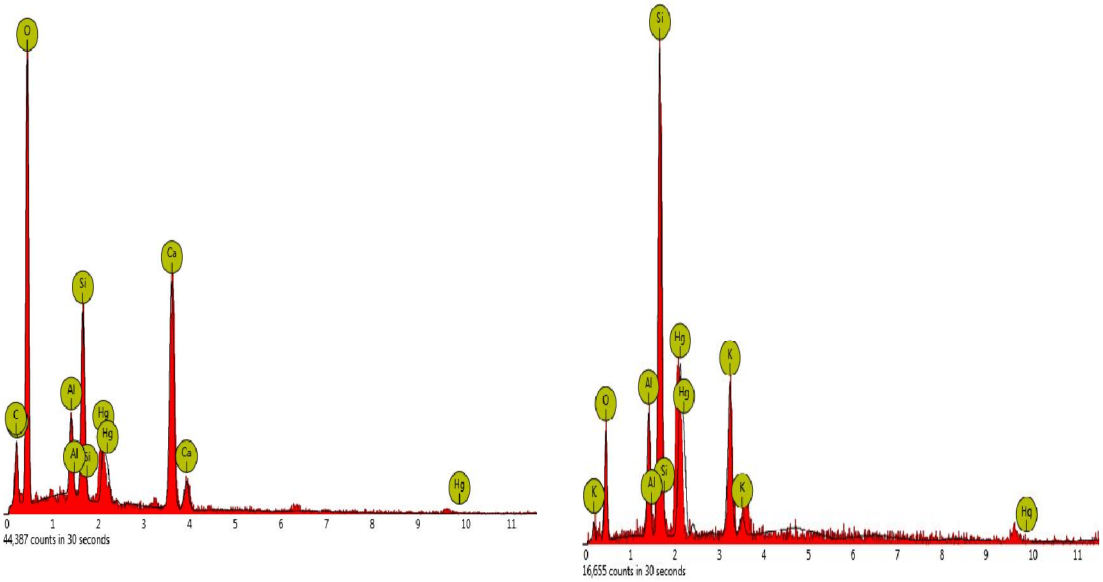


Fig. 8. Measure of alkalinity (PH value) of concrete samples

SEM images from the analyses revealed deep cracks at several spots throughout the river and hand dug well concrete samples (Fig. 10). On the other hand, the tap water specimen had less cracks, and this could be due to less chemical impurities as the EDS analysis revealed. One major function of water in concrete is to wet the surface of aggregates to develop adhesion because the cement paste adheres to aggregates. However, the presence of chemical impurities in the river, used during the concrete mix, could reduce its adhesive abilities and thereby reduce the strength of the concrete as indicated earlier in Table 2. Chemical impurities had the tendency of causing chemical reactions within the concrete mix and could therefore affect the bonding strength of the mixture, hence reducing the strengths of the concrete samples mixed with contaminated water from the “galamsey” areas (Olugbenga, 2014). The presence of cracks in concrete adversely affects the strength of the concrete. This could be due to the fact that the cracks served as conduits for fluid transportation which might have facilitated chemical reactivity within the concrete and subsequently led to reduction of the strength of the concrete samples mixed with water from the “galamsey” areas.

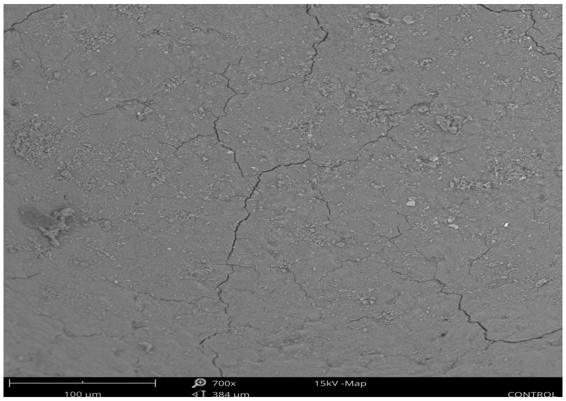


(A) tap water **(B) hand-dug well**

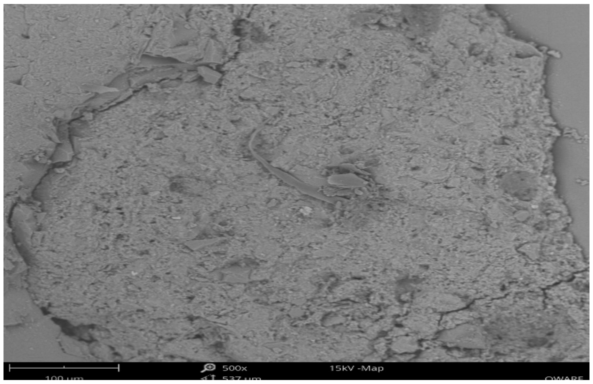


(C) borehole **(D) river**

Fig. 9. EDS images of chemicals in concrete sample (A = tap water, B = hand-dug well, C = borehole, D = River)

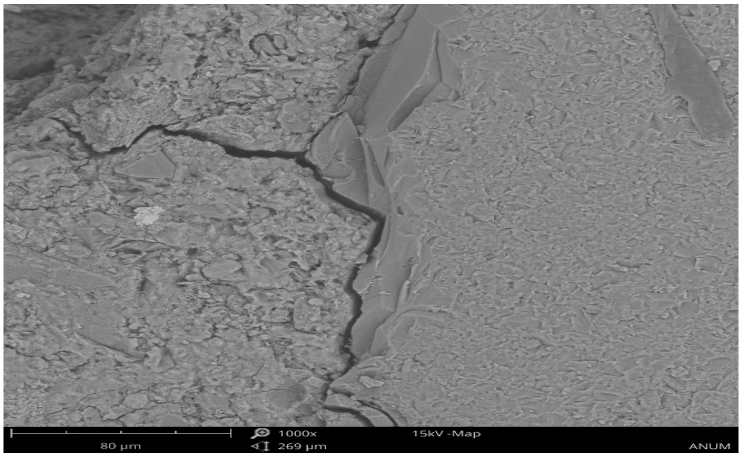


(a) Tap water



(b) Borehole

(c) Hand-dug well



(d) River

Fig. 10. SEM images of concrete samples from water sources (a) tap water (b) borehole (c) had-dug well (d) river

4. CONCLUSION

The performance of concrete samples mixed and cured with different water sources, namely: tap water, river, borehole and hand-dug well from “galamsey” areas were studied. The objective of the study was to assess the quality of the different sources of water (river, hand-dug well, borehole) in the small scale mining areas, and determine the influence of the water on the properties of the concrete produced with the water sources. Results indicated that concrete mixed with water from the water sources in the “galamsey” areas had their early compressive strength lowered by 21%, 18% and 13% for water from the river, hand-dug well and borehole respectively compared to the controlled sample (tap water). After 180 days of immersion in $MgSO_4$ solution, the concrete with water from the tap, borehole, hand-dug well and river lost about 32%, 35%, 34% and 38% respectively of their compressive strength. It was noted that the concrete specimens produced from the three water sources performed relatively poorly in strength, sulphate attack and alkalinity level, therefore making the concrete mixed with untreated water from the “galamsey” areas in Ghana not suitable for concrete and reinforced concrete production. The deep cracks as observed in the morphology of the concrete specimens mixed with water from the rivers could be due to the presence and reaction of chemical impurities in the water used. This study recommends that water from any of the water sources in the "galamsey" areas of Ghana be treated before using for concrete production.

DISCLAIMER

The products used for this research are commonly and predominantly used in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Neville AM. Properties of concrete. 4th ed. ELBS Longman;1996.
2. Yalley PP, Appiadu-Boakye K, Adzraku WD. Assessing qualities of different sources of water for mixing concrete. Journal of Engineering Research and Reports.2019;5(4):1-8.
3. Gbenga MA. Water quality effect on concrete compressive strength; Ogunpa stream water case study. Civil Engineering Horizon Online Journal; 2014.
4. WHO-UNICEF. Progress on Drinking Water and Sanitation: 2012 Update. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation Report. United States of America; 2012.
   ISBN: 972-924-1503297.
5. Asiam EK, Buaben E. Some Environmental Issues of Inland Valleys: A Case Study. Ghana Mining Journal. 2008;38-42.
6. Gyamfi E, Appiah-Adjei EK, Adjei, KA. Potential heavy metal pollution of soil and water resources from artisanal mining in Kokoteasua, Ghana. Groundwater for Sustainable Development. 2019;8:450-456.
   DOI: 10.1016/j.gsd.2019.01.007
7. Al-Hassan S, Amoako R. Environmental and security aspects of contemporary small scale mining in Ghana. 3rd UMaT Biennial International Mining and Mineral Conference Proceedings. 2014;146-151.
8. Aryee BNA., Ntibery BK, Atorkui E. Trends in the small-scale mining of precious minerals in Ghana: a perspective on its environmental impact. J Clean Prod. 2003;11(2):131–140.
9. Dorleku MK, Nukpezah D, Carboo D. Effects of small-scale gold mining on heavy metal levels in groundwater in the Lower Pra Basin of Ghana. Applied Water Science. 2018;8:126
10. Donkor AK, Bonzongo JJ, Nartey VK, Adotey DK. Heavy Metals in Sediments of the Gold Mining Impacted Pra River Basin, Ghana, West Africa. Soil and Sediment Contamination. 2005;14(6):479-503.
11. Kpan J, Opoku B, Gloria A. Heavy Metal Pollution in Soil and Water in Some Selected Towns in Dunkwa-on-Offin District in the Central Region of Ghana as a Result of Small Scale Gold Mining. Journal of Agricultural Chemistry and Environment. 2014;**3:**40-47.
    DOI: 10.4236/jacen.2014.32006
12. Kwaansa-Ansah EE, Adimado AA, Ephraim JH. Distribution of mercury in water, sediment and fish from the Volta lake and its major tributaries. J Environ Occup Sci. 2012;1(1):27-36
13. Duncan AE, De Vries N, Nyarko KB. Assessment of heavy metal pollution in the main Pra river and its tributaries in the Pra Basin of Ghana. Environmental Nanotechnology, Monitoring & Management. 2018;10:264–271.
14. Donkor AK, Nartey VK, Bonzongo JJ, Adotey DK. Artisanal mining of gold with mercury in Ghana. West Africa Journal of Applied Ecology. 2006;9:2–18.
15. Smolders A, Lock R, Van der Velde G, Hoyos RIM, Roelofs JGM. Effects of mining activities on heavy metal concentrations in water, sediment, and macroinvertebrates in different reaches of the pilcomayo river, South America. Archives of Environmental Contamination and Toxicology. 2003;44:0314–0323.
16. Amic A, Tadic L. Analysis of basic physical-chemical parameters, nutrients

and heavy metals content in surface water of small catchment area of Karašica and Vučica Rivers in Croatia. Environments. 2018;5(2):20.
DOI: 10.3390/environments5020020.

17. BS EN 197-1. Cement Part 1: Composition, specifications and conformity criteria for common cements. BSI Standards Publication: London; 2011.
18. BS 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. BSI Standards Publication: London; 2002.
19. BS EN 12620. Aggregates for concrete. BSI Standards Publication: London; 2008.
20. BS EN 12390-2. Testing hardened concrete Part 2: Making and curing specimens for strength testing. BSI Standards Publication: London; 2019.
21. GS 175-1. Water quality - specification for drinking water. Ghana Standard Board: Accra; 2009.
22. BS EN 12350-2. Testing fresh concrete Part 2: Slump-test. BSI Standards Publication: London; 2019.
23. BS EN 12390-3. Testing hardened concrete Part 3: Compressive strength of test specimens. BSI Standards Publication: London; 2019.
24. BS EN 12390-5. Testing hardened concrete Part 5: Flexural strength of test specimens. BSI Standards Publication: London; 2019.
25. ASTM C1012. Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution. ASTM International, West Conshohocken, PA; 2018.
26. ISO/TS 24597. Microbeam analysis — Scanning electron microscopy — Methods of evaluating image sharpness. International Standards Organization: Geneva; 2011
27. Park K, Noguchi T. Effects of mixing and curing temperature on the strength development and pore structure of fly ash blended mass concrete. Advances in Material Science and Engineering. 2017.
DOI: 10.1155/2017/3452493
28. John AT, Nelson TA. The Effect of the Presence of Ferric Iron in Water used for the Production of Concrete on Its Compressive Strength. European Journal of Engineering Research and Science. 2019;8.
29. Wieslawa N, Barbara T, Sylwia D. The properties of cement pastes and mortars processed with some heavy metal nitrates containing solutions. Procedia Engineering. 2015;108:72-79.
30. Reddy BM, Reddy IVR. Effect of heavy metal and magnesium sulfate on properties of high strength cement mortar. Journal of Civil Engineering and Construction Technology. 2011;2(8):160-168.

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