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The Auditory Working Memory of 13-15-Year-Old Adolescents Using Water with Varying Fluoride Concentrations from Selected Public Primary Schools in North Kajiado Sub County

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Abstract Water contributes significantly to the physiological functions in the in the human body. However, low fluoride doses have been reported to affect the central nervous system (CNS) without first causing the physical malformations of dental and skeletal fluorosis. Aims and objectives were to determine fluoride concentrations in water used by adolescents who were born and raised in North Kajiado and correlated it with their Auditory Working Memory Index (AWMI). The survey was cross-sectional and descriptive involving 269 school children aged 13-15 years. A purposeful sampling frame was used to select the schools. Fluoride in water was determined using the Fluoride Ion selective electrode. The AWM was assessed using the Wechsler intelligence scale for Children V (WISC-V) subtest. The mean auditory working index for the group was 111.5±22.6 while the boys had a mean AWMI of 111.46±22.37 and the girls 111.56±22.75. A comparison of the AWM of children from low (105.40±23.6) and high (99.52±23.2) fluoride schools and medium with high fluoride school had significant differences. The AWM for the children whose household water had low fluoride had higher AWMI 122.58±19.9 compared to those whose household had high fluoride in the with ANOVA F (2, 266) = 17.968, p≤.0001 and Tukey HSD for low and medium (m=-5.919, se=3.146, p=.145, low and high fluoride, (m=-18.559. se=3.124, p≤.001; medium and high (m=-12.640, se= 3.32, p≤.001 at 95% CL. In conclusion, low fluoride in the water seemed to enhance the AWM. However, the AWM declined with an increased in the fluoride concentration in water.

Keywords Auditory working memory, Fluoride in household water, Adolescents

1. Introduction

Fluoride is a chemical ion of fluorine which forms during rock formation and occurs naturally in the earth's crust. Fluoride leaches and weathers into groundwater [1]. Water is the primary source of fluoride in the human body [2]. Other sources of fluoride include diet especially tea and fish and inhalation in places where coal mining is undertaken especially in China.

In dentistry, fluoride has been used in the prevention of dental caries, and when used in low doses it has been shown that fluoride will increase the resistance to dental caries [3]. However, in higher doses of fluoride has been shown to increase dental fluorosis, skeletal fluorosis and also affect the development of the intellect [4, 5, 6].

Several studies have been done on both animals and humans to show the effect of fluoride on the memory and hence its impact on learning [7]. Reviews of studies have done on animals on the results of fluoride if any on the outcomes of neurobehavioural have concluded a moderate level of evidence adverse effects of exposures.

A study on foetuses from endemic high fluoride areas had shown high levels of epinephrine and decreased norepinephrine levels which led to a reduced level of alertness. The increased level of epinephrine may be due to reduced metabolic enzymes or inhibition of the pathway that converts it to norepinephrine. It was also found that the exposed group to fluoride had significantly impaired reaction time, pursuit aiming, digit span, Benton visual retention and digit memory [8, 9]. In experimental animals at Water drinking concentrations of more than 100ppm of fluoride, studies have shown performance deficits in rats on memory tasks and learning [10]. There are no studies in Kenya hence the aim was to determine fluoride concentrations in water used by adolescents who were born and raised in North

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Kajiado and correlated it with their Auditory Working Memory Index (AWMI).

2. Materials and Methods

The study was conducted in the Kajiado North Subcounty in North Kajiado in the Great rift valley which is also part of peri-urban Nairobi as a cross-sectional descriptive study.

Sampling frame: The schools were first purposefully selected then divided into low, medium and high water fluoride areas. Participants in each of the schools were given the consent forms after explanation of the nature of the study to take to their parents to sign the consent form. Those who brought back the signed consent forms were given a clean labelled plastic bottle to collect the water they used domestically and a questionnaire to be filled by the parent. Those who brought back the water and filled survey form were recruited for the study.

Sampling and sample size: The sample size calculation where by $N=2(Z_{1-\alpha/2}+Z_{1-\beta})$ p (1-p)/ $(P1-p2)^2$; Where N was the desired sample size. $Z_{1-\alpha/2}$ was the confidence level at 95% (SD 1.96) while, $Z_{1-\beta}$ is 1.28 β=10%, i.e. 95% clarify power. P was the mean difference between prevalence of p_1 (61.8%) and p_2 (38.2%); with $N=2(1.96+1.28)^2(0.236)$ (1-0.236)/ $0.618-0.382)^2$ = 67 per group and 74 children per group was used to cater for attrition.

Participant inclusion and exclusion: The participants were 13-15-year-olds born and brought up in Kajiado county, Kajiado north subcounty and those who moved in early childhood by the age of four years old. They had to have been residents of the area for a continuous period without outward migration for a minimum period of seven years. Also, the children were excluded if they had any chronic illnesses.

Fluoride Exposure assessment: By being residents of Kajiado North, Kajiado county the participants have been exposed to various degrees of fluoride that occurs naturally in Drinking Water. From previous studies with samples taken from different parts of Kajiado county indicate fluoride levels in the range of 0.1-10mg/l [11, 12]. The mean water fluoride content of Kajiado county was not available both at the county and ministry of water.

Water sampling and analysis: the water samples were collected from water sources in and around the schools. The water was then taken to the government chemist for water fluoride analysis and department of mines and geology for lead, arsenic and copper analysis. Each child was given a clean, dry polyurethane bottle in which they were instructed to collect some water from the water used in the household. The water was stored in a refrigerator and taken to the government chemist the next day for fluoride analysis was none using the Orion Fluoride Ion electrode. A total of two hundred and sixty-nine water samples form the children's household water supplies c and analysed.

Instruments for data collection: Each child had their social demographic data collected by a questionnaire form.

Auditory working memory: The auditory working memory was evaluated with the children in a spacious classroom where each child was placed one metre from the other. The children did a digit span and letter-number sequencing sub-test of WISC-V for AWM [13]. The oral test was done while they were seated on a chair facing the window and the teeth dried using gauze before the exam. They then proceeded to a room of almost thirty (the place selected was a quiet room) and did a digit span and letter-number sequencing test of WISC-V for Auditory Working Memory (AWM) [13].

Calibration for AWM was done by a qualified psychologist author three, and Cohen Kappa was 89% for the first author and 92% for the third author which were acceptable. The collected data was recorded on individual forms. The AWM was based on a scale by Weschler Intelligence Scale for Children, fifth edition (WISC-V) using the digit span and letter-number sequencing [13]. The digit span and letter-number sequencing were added to give the sum of scaled scores. The sum of scaled scores was then converted to an auditory working memory index which eas obtained from the WISC V manual. The working memory index was then categorised as gifted 120 and above; above-average 110-119; average 90-109; 80-89 below average; mentally challenges as 79 and below [13].

Ethical clearance: The Kenyatta National Hospital/ University of Nairobi Ethics committee, National Commission of Science Technology and Innovation (NACOSTI), Kajiado county education office and Kajiado county commissioners office approved the study. The participants were informed of the nature of the research and its procedures before being given consent forms to take to their parents and or guardians for signing to participate in the study. Only those whose parents had given consent and the children assented to participate were allowed to participate in the study.

Data analysis: The SPSS Version 20 was used to analyse the data. All the variables had descriptive statistics done. Statistical tests for differences were conducted using a t-test, chi-square for categorical variables and Analysis of Variance (ANOVA) and Tukey Honestly Significant post hoc tests to compare exposure within groups and means according to the distribution of each variable. A spearman's association coefficient was used to measure the correlation between water fluoride and AWM, the degree of dental fluorosis and AWM. To assess any associations between all the assessed variables with AWM a regressional model was applied.

3. Results

Socio-demographic characteristics: The distribution of the children by gender and age was that a total of two hundred and sixty-nine adolescents whose parents had given consent and allowed to participate were recruited to join the survey. Out of the 268 children, 178 (66.2%) were girls, and 91 (33.8%) were boys. There were more females whose caregivers gave consent as compared to boys. Above a third 184 (68.4%) were thirteen-year-olds, of whom 127 (63%) were girls, and 57 (37%) were boys. In the 14-year age group of fourteen-year-olds were 58 (21.5%) of whom thirty eighty (65.5%) were girls and twenty (34.5%) were boys. In the fifteen-year age category, they were twenty-seven (10%) of whom fourteen (51.9%) were boys, and thirteen (48.1%) were girls, Figure 1.

Place of Birth: Two hundred and thirty-seven (88.1%) were born and raised in Kajiado North sub- County while thirty-two (11.9%) were born outside Kajiado North sub-County. The high number of children born in North Kajiado was an indication that most of the children were exposed to the fluoride in the drinking water from pregnancy. Also, it was an indication that they grew up in a similar socio-economic setup. The children born outside Kajiado north subcounty and moved in the county before the age o four were sixteen (50%) while the other sixteen (50%) were born in Kajiado county but not Kajiado north subcounty. None of the participants had a chronic illness considered detrimental to the development of intellect Figure 2.

The distribution of the children according to the household water fluoride concentration: Fifteen (5.58%) children had their household fluoride concentration of 0-0.5mg/l, fifty-two (19.33%) had fluoride level between 0.6-0.8 mg/l and thirty-eight (14.12%) had fluoride between 0.9-1 mg/l. The water fluoride level between 1.1-1.8 mg/l was used by forty-one (15.24%) of the population, forty-four (16.36%) of the study population used water with fluoride between 1.9-2.5 mg/l while seventy-nine (29.37%) used water with fluoride above 2.5mg/l Figure 3.

AUDITORY WORKING MEMORY INDEX:

The mean is 111.53 with a standard deviation of 22.578. The distribution is a normal one, Figure 4.

THE AUDITORY WORKING INDEX

The auditory working memory Index by gender: The mean AWMI for the 269 children was111.53±22.58 while the mean AWMI for the 91(33.8 %%) boys was 109.07±23.24 while 178 (66.2 %%) girls had a mean AWMI of 112.79±22.193 Figure 5.

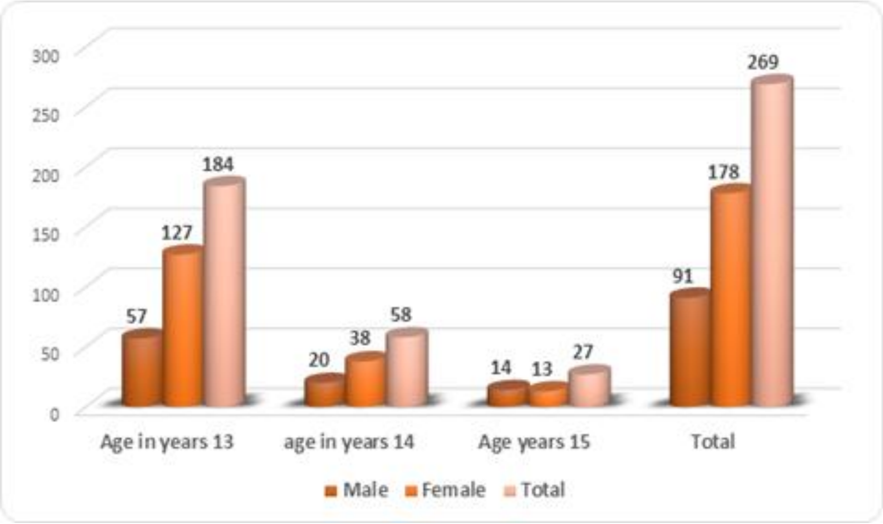

Figure 1. The distribution of respondents by gender age

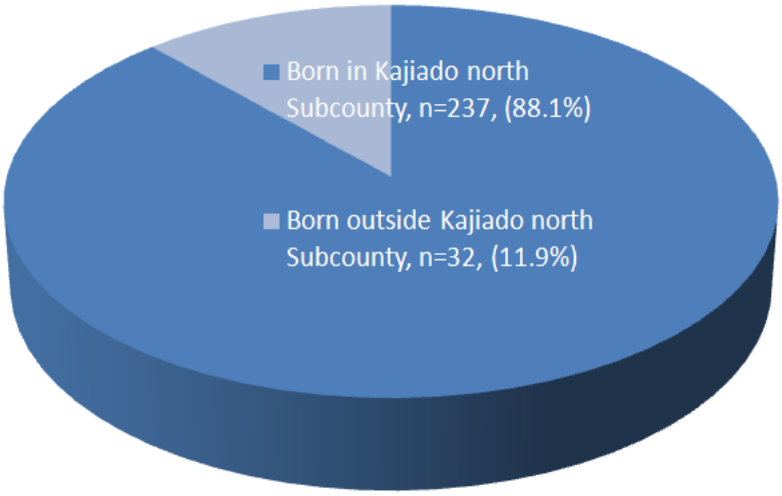

Figure 2. Distribution of the children according to the place of birth

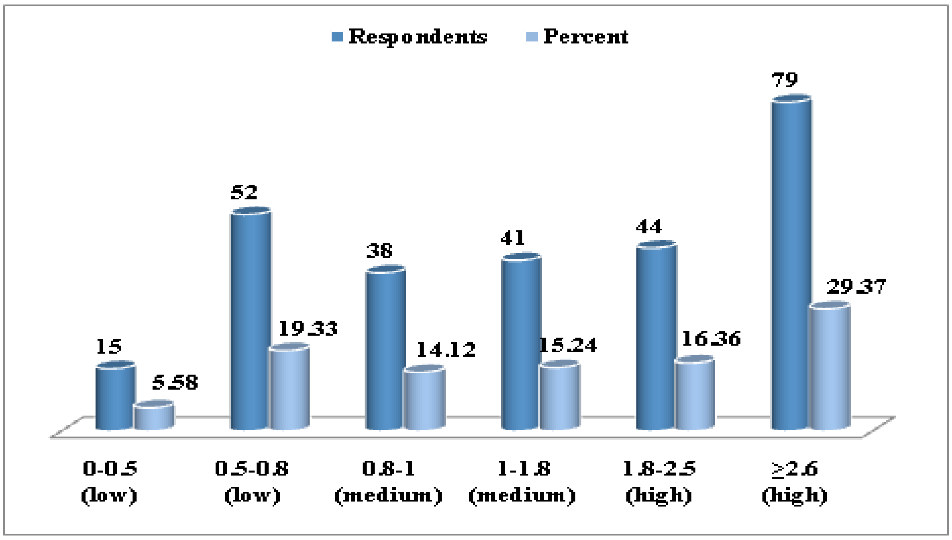

Figure 3. The distribution of fluoride in household water

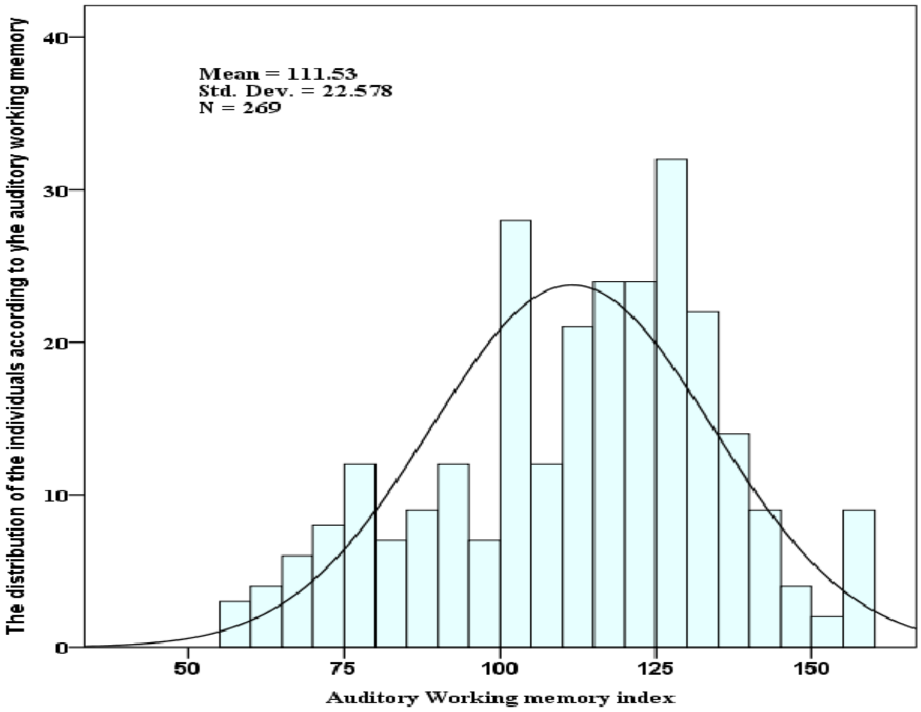

Figure 4. The auditory working memory index

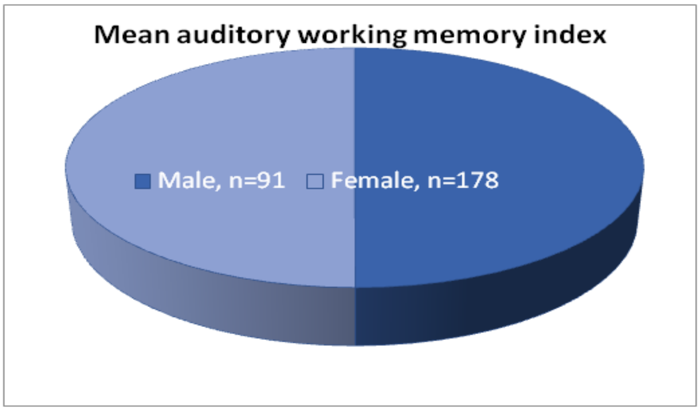

Figure 5. The mean auditory working memory index and gender

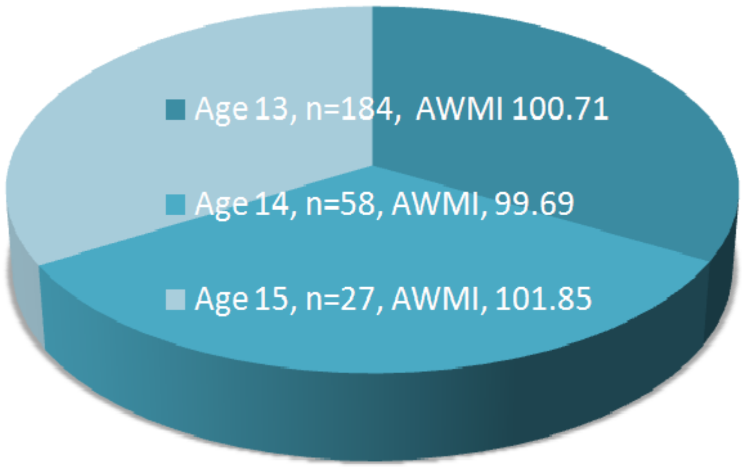

Figure 6. The means for auditory working memory Index by age

The differences in the means between the boys and the girls were insignificant with an independent sample test where a Levene's t-test for equality of variances was negligible with F (267, 184.1) =0.039, t = (-.034, -.035), p=.972 (≤0.05).

The Mean Auditory working memory index by Age groups: The children were categorised into age groups between 13-15 years. The thirteen-year-olds were 184 (68, 4%) had a mean auditory working memory of 113.21±21.810 while fourteen-year-olds were 58 (21.6%) with an AWM of 108.71±24.84 and the fifteen-year-olds was 27 with a mean AWM of 106.15±22.06, Figure.

An ANOVA test showered there were insignificant differences in the AWMI within and between the ages with F (2, 266) = 1.737, p=.178at 95% CL, Figure 6.

The auditory working index and School water fluoride(Low, Medium, and High)

The overall mean auditory working memory Index for the 269 children was 111.53±22.58 SE=1.377 with a 95% CL.

Low (≤0.9mg/l) fluoride in the school water: In the low fluoride area there were sixty eighty (25.4%) of the children had a mean AWMI of 116.66±20.410, SE=2.475. The respective lowest and highest AWMI was 55 and 155, while the 95% CI for mean was (111.72, 121.60, Figure 7.

Medium fluoride (≥1mg/l to ≤1.6mg/l) in the school water: In the schools with the medium fluoride in the water supplies and the environs 33 (12.3%) children had a mean AWMI of 128.00 ±18.99, SE=3.31, while the children with the lowest AWMI had 76 and the highest 155 with a 95% CI for the mean of (121.27, 134.73), Figure 7.

High fluoride (≥1.6mg/l) in the school water: For 168 (62.5%) children from the high school water fluoride the mean AWMI was 106.21±22.12, SE=1.706 with a minimum and the highest as 55 and 155 with a 95% CI for the mean of (102.85 and 109.58), Figure 7.

An ANOVA analysis indicated significant difference between the groups for the AWMI of adolescents living in low (≤0.9mg/l), medium (≥1mg/l to ≤1.5mg/l) and high fluoride (≥1.6mg/l) areas in Kajiado north subcounty, Kajiado County, with a value for F (2,266) = 17.008, p≤.001 at 95% CL.

Tukey Post Hoc test showed significant differences in the mean AWMI to between low fluoride (≤0.0 to 9mg/l) and medium (1mg/litre to1.5mg/litre) in school water fluoride and the water of the environs. The mean difference was -11.338, SE= 4.527 and p≤.034 at 95% CL. Similarly, significant differences were shown in the mean AWM between low fluoride (≤0.9mg/l), and high fluoride (≥1.6mg/l) fluoride with a mean difference of 10.447, SE=3.067, p≤0.002 at 95% CL. Also, significant differences were noted between the medium water fluoride area and the high water fluoride a mean difference of -21.786, SE= 4.063 p≤0.001 at 95 %CL.

The auditory working memory and the Household water fluoride concentration: The 269 children had a mean AWM score of 111.53±22.578, SE=1.377 and a 95% CI for the mean as 108.82, 114.24 while the minimum score was 55 and the maximum was 155.

Low fluoride concentration in the household water: The household water whose fluoride concentration ranged low fluoride had 105 (39%) children, and the mean AWMI was 123.04±17.967, SE= 1.377 with a 95% CI for a mean of (119.56, 126.52). The child with the lowest AWMI score had 65, and the highest score was 155, Figure 8.

Medium fluoride concentration in the household water: The households whose water content had medium fluoride the mean AWMI for Eighty-one (30.1%) individuals were 103.89±21.271, SE =2.363 with a 95% CI for a mean of (99.19, 108.59) with the lowest score as 55 and the highest as 142, Figure 8.

High household water fluoride concentration: Eighty-three (30.9%) children in had household water samples with high fluoride concentration in the range between 1.6 and above mg/litre. The children had a mean AWMI of 104.42±23.169, SE=2.543, with a 95% CI for a mean of (99.36, 109.48) and the minimum score was 55 while the highest was 155, Figure 8.

An ANOVA test analysis for multiple comparisons of means indicated significant differences between the means for the AWM index with the value for F (2, 266) = 17.968, p≤0.001. A Tukey HSD post Hoc showered significant differences in the means to between the mean AWMI scores for the children in the low and medium fluoride concentration in the household water samples with the M= -19.149, SE=3.059, p≤.001. Similarly, the mean differences in the AWM for children whose water samples had low fluoride were significantly different from the AWMI scores for the children whose households had high fluoride concentrations with (M=18.616, SE=3.038) p≤.001 at 95% CL. However, insignificant differences in the means for AWMI scores was observed when the AWMI means for the children whose household water had medium fluoride and those whose household water had high fluoride in their household water samples with (M= -.533, SE=3.230), p≤.985 at 95% CL.

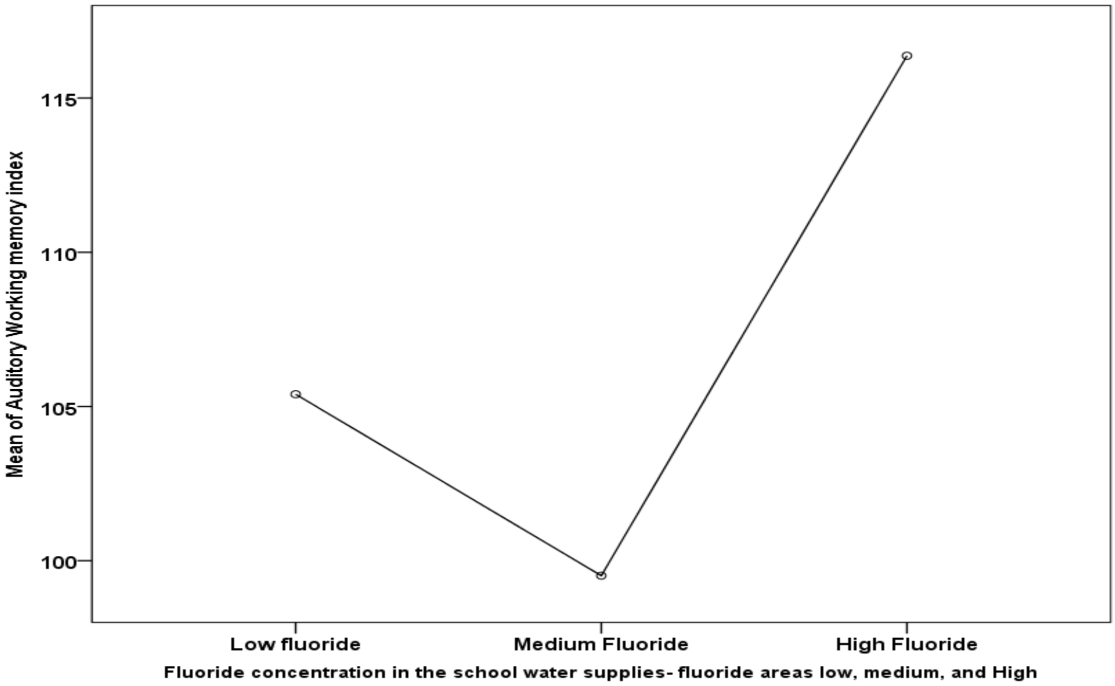

Figure 7. Fluoride concentration in the School Water supplies-fluoride areas low, medium, and High

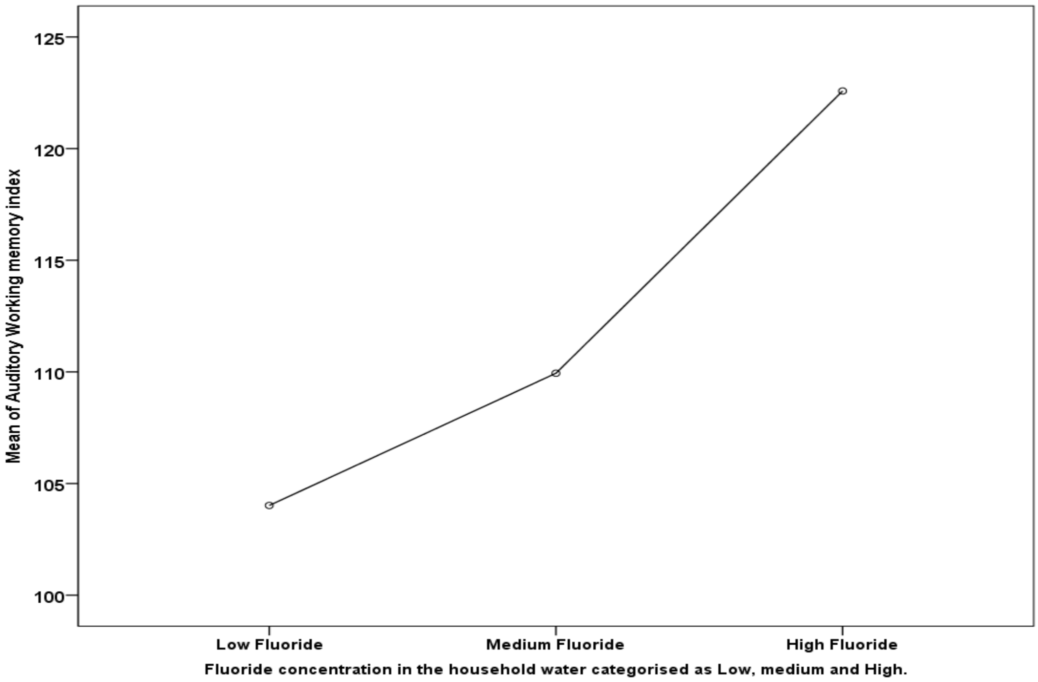

Figure 8. Fluoride concentration in the household water categorised as Low, medium and High

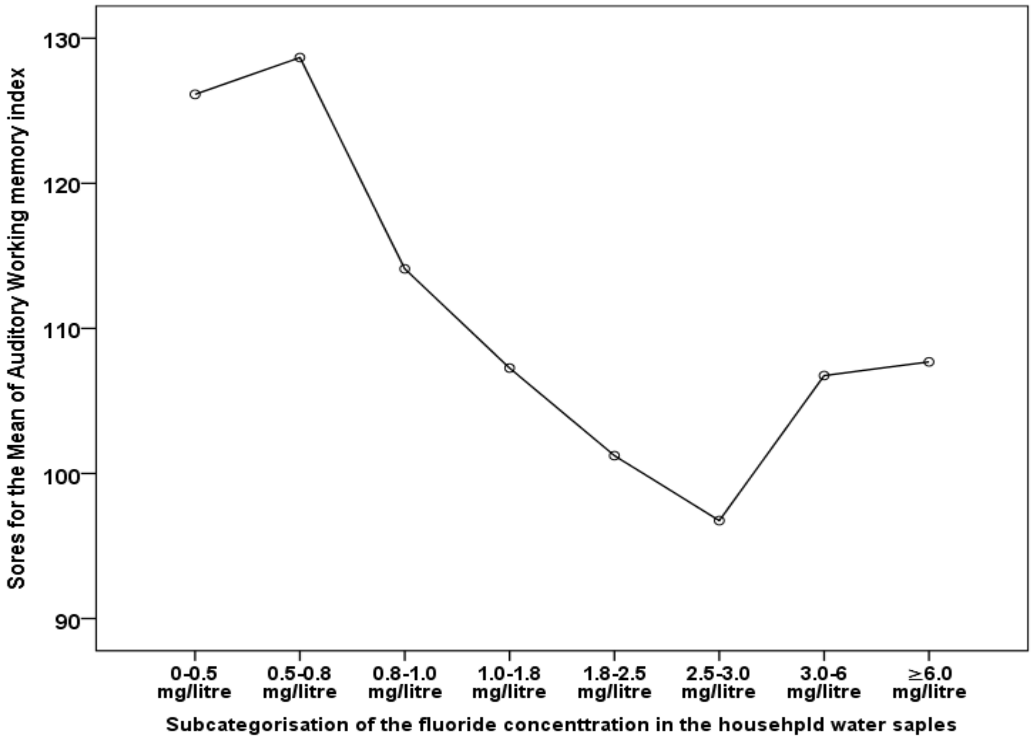

Figure 9. The decrease in the auditory working index mean with an increase in the fluoride concentration in the household water

The categorised household water fluoride concentrations and the auditory working index: The mean auditory working index for the 269 in the survey group was 111.53±22.578, SE =1.37 and a 95% CL for a mean of 108.82, 114.24 while the lowest score was 55 and the highest 155. The auditory working memory had the household water fluoride samples of the children was subcategorised. Out of the 269 individuals, 15 (5.6%) used household water with a fluoride content which was between 0-0.5 mg/ litre and the mean AWMI was 95.80±19.36. The auditory working memory was high for children who used water with a low fluoride concentration in the household water and it was highest at 0.5-0.8 mg/litre of fluoride. Then the auditory working memory score decreased as the fluoride level increased. The lowest score was at 2.5-3 mg of fluoride in the water and was raised slightly above three and seemed to level out gently above six **Figure 9**.

An ANOVA test for multiple comparisons indicated that there were significant differences in the auditory memory within and between groups varying concentrations of fluoride in the household water samples sampled by a child with F= (7, 261), p≤.001 at 95% CL.

0-0.5 mg/litre fluoride in household water: Fifteen (6%) used household water which had a fluoride ranging between 0.0-0.5 mg/litre of fluoride and there AWMI was (115.52, 136.75) with a 95% CL as mean as (115.52, 136.75) and the lowest score as 94 while the highest as 155, **Figure 9**.

A Tukey HSD Post hoc test showered insignificant differences between the AWM of children whose household water samples had ad a fluoride concentration of 0.0-0.5 and that of the children whose water contained fluoride ranges of 0.5-8 mg/litre, 0.8-1 mg/litre, 1-1.8 mg/litre and 1.8-2.5 mg/litre respectively. The respective mean difference, the standard error of the mean difference and the level of significance were; 0.5-0.8mg f/litre, – (M=.540, SE=5.914), p=1.0; 0.8-1.0 mg fluoride/litre (M=12.028, SE=6.153), p=515. Also, concentrations of 1-1.8 fluoride/litre (M=-11.989, SE=6.343), p=.559; 1.0-1.8 mg fluoride/litre, (M=18.865, SE=6.089), p≤.044; 1.8-2.5 mg fluoride/litre, (M=24.906, SE=6.034), p≤.001; and 2.5-3.0 mg fluoride/litre, where (M=29.383, SE=6.642), p≤.001 at 95% CL. However, there were insignificant differences in the AWM for the children whose water samples had a low fluoride concentration which ranged between 0.0 to 0.5 mg/litre when compared to that of individuals who used water with a fluoride concentration between 3-6 mg/litre. The mean difference was (M=19.383, SE=7.253), p=.136; similarly, children whose water had a fluoride concentration of 3.0-6 mg/litre had a nonsignificant mean difference of (M=18.441, SE=6.131), p=.057at 95% CL.

0.5-0.8 mg/litre fluoride in household water: Fifty-two (19%) individuals aged 13-15 years used water with a fluoride concentration of 0.5-0.8 mg/litre and their mean AWMI was 128.67±15.00, SE=2.081, and a 95% CL for mean of (124.50, 132.85) and the lowest score as 55 while the highest was 155. The mean auditory working memory index of the children who used household water with a fluoride concentration range 0.5-0.8 mg/litre had multiple comparisons with a Tukey post hoc test where the mean AWMI of the individuals whose household water contained fluoride categories of, 0.8-1.0mg/litre, 1.0-1.8 mg/litre, 1.8-2.5 mg/litre, 2.5-3.0 mg/litre, 3.0-6 mg/litre.

Comparisons were significant between means for the AWMI of the children using water with fluoride 0.5-0.8 mg/litre with that of the individuals who used the indicated ranges of fluoride concentration in the drinking household water. The mean differences (m) were significant for 0.8-1.0mg/litre (M=14.568, SE=4.307), p≤.019 at 95% CL;1.0-1.8mg/litre (M=21.405, SE= 4.215), p≤.001 at 95% CL; 1.8-2.5 mg/litre (M=27.446, SE=4.134), p≤.001 at 95% CL; while 2.5-3.0 mg/litre ((M=31.923, SE=4.980), p≤.001 at 95%CL. Also, significant differences were noted between the AWMI for the children who used 0.5-0.8 mg/ litre fluoride concentration in the household water and those who used the fluoride concentration of range for 3.0-6ppm in their water with the mean difference of (M=21.923, SE=5.769), p≤.004 at 95% CL. Also, the children whose water fluoride was ≤6 mg/litre had significant differences in the AWMI with the children who used 0.5-0.8 mg/litre with a mean difference of (M=20.981, SE=4.275), p≤.001at 95% CL.

0.8-1.0 mg/litre fluoride in household water: Thirty eighty (14%) individuals had the household water fluoride content of 0.8-1.1 mg/litre fluoride (medium), and their mean AWM was 114.11±18.10, SE=2.936 with a 95% CL for mean of (108.16, 120.05) with the lowest score as 65 and the highest as 155, **Figure 9**. A Tukey HSD post hoc test showered insignificant difference between the AWMI for children who used water with a fluoride concentration range of 0.8-1.0mg/litre when compared with the AWMI of the children who used water with the fluoride ranges of and subcategories 1.0-1.8 mg/litre with a mean difference (6.837, SE=4.544), p=.805 at 95% CL; 1.8-2.5 mg/litre, (12.878, SE=4.469), p=.081at 95% CL. Similarly, the comparisons with 2.5-3.0 mg/litre, (17.355, SE=5.262), p=.024 at 95% CL; and 3.0-6mg/litre, (7.355 SE=, 6.014), p=.925 at 95% CL.

95% CL were non-significant. Also, insignificant differences were noted in the mean AWMI of the children whose water had a fluoride concentration in the household water which ranged between were 0.8-1.0 / litre when compared to the AWMI of the children who used water with a fluoride concentration of ≥6.0mg/litre with a mean difference of -(6.413, SE=4.600), p=.859 at 95% CL.

1-1.8 mg/litre fluoride in household water: There were 414 (15.2%) individuals used water with a mean fluoride in the household water of 1.0 -1.8 mg/litre which was categorised as high and their mean AWMI was 107.27±20.23, SE=3.160, with a 95% CL for mean of (100.88, 113.66) with a minimum as 59 and the maximum as 142, **Figure 9**. Forty-one children with a mean AWMI of 110.86 and used household water with a fluoride content of 1. -1.8 mg/litre had their AWMI compared with the mean AWMI of the children whose water contained 1.8-2.5, mg/litre, 2.5-3.0mg/litre, and 3.0-6 mg/litre. A Tukey HSD post hoc test showered insignificant differences with the respective values as (6.041, SE=4.380), p=.866; (10.518, SE=5.187), p=.465 at 95% CL; and (.518, SE=5.948), p=1, at 95%CL. Also, when the AWMI of the children who used household water with a fluoride concentration of 1. -1.8 mg/litre fluoride was compared with the AWMI (129.64) of the children whose water had a fluoride concentration of ≥6.0 mg/litre of fluorides insignificant differences were observed with (-.424, SE=4.514), p=1 at 95% CL.

1.8-2.5 mg/litre fluoride in household water: Twenty-four (8.9%) adolescents used water with a fluoride content which ranged between 2.5-3.0 mg/l and their mean AWMI was 101.23±22.14, SE=3.338, and a 95% CL for a mean of (94.50, 107.96) with the minimum score as 55 and the highest as 146, **Figure 9**. A Tukey post hoc test indicated insignificant differences between the AWMI of the children who used household water with 1.8-2.5 mg/litre fluoride and those whose household water contained 2.5-.0mg/litre, and 3-6mg/litre of fluoride. The respective mean differences which were insignificant were (4.477, SE=5.121), p=.988 at 95% CL; (-5.523, SE=5.891), p=.982 at 95% CL; and (-6.465, SE=4.438), P=.829 at 95% CL.

2.5-3 mg/litre fluoride in household water: Sixteen (5.9%) whose water fluoride ranged between 3-6mg/l of fluoride had a mean AWMI of 96.75±20.03, SE=4.089, and a 95% CL for a mean of (88.29, 105.21) while the lowest score was 62 and the highest 132, **Figure 9**.

A comparison of the AWMI for the children who used water with 2.5-3mg/litre of fluoride with that of the children who used 3.0-6 mg/ litre and ≥6.0 mg/l of fluoride respectively based on a Tukey post hoc test. Both water fluoride concentrations had insignificant differences with the mean differences of (-10.000, SE=6.513), p=.788 and (-10.942, SE=5.235), P=.424 at 95% Cl.

3-6 mg/litre fluoride in household water: Thirty-nine (14.5%) children whose water the fluoride content was ≥6mg/l hand a mean AWMI of 107.69±24.25, SE=3.883and a 95% CL for a mean of (99.83, 115.55) where the minimum was 62and the maximum 142, **Figure 9**.

The children who used water with the fluoride concentration of 3.0-6mg/litre had their auditory working memory index compared with the AWMI of the children who used household water with ≥6.0 mg/litre of fluoride. The non-significant difference was observed with a mean difference with (M=-.942, SE=5.991), p=1.0 at 95% CL.

AUDITORY WORKING MEMORY

Levels of Auditory working memory by gender auditory working memory (AWM) was considered for the 269 adolescents, and one hundred and sixteen (43.12%) individuals were gifted out of whom, thirty-four (12.64%) were males, and eighty-two (30.48%) were females. However, there was forty-five (16.73%) who had an above average working memory of whom thirteen (4.83%) were male while thirty-two (11.90%) were female. Fifty-nine (21.93%) had an average AWM of whom twenty-three (8.55%) were male s while thirty-six (13.38%) were females. Sixteen (5.95%) adolescents had below average AWM of whom; five (1.86%) were males while eleven (4.09%) were females. Out of the thirty-three (12.27%) mentally challenged children sixteen (5.95%) were males and seventeen (6.32%) were females **Figure 10**.

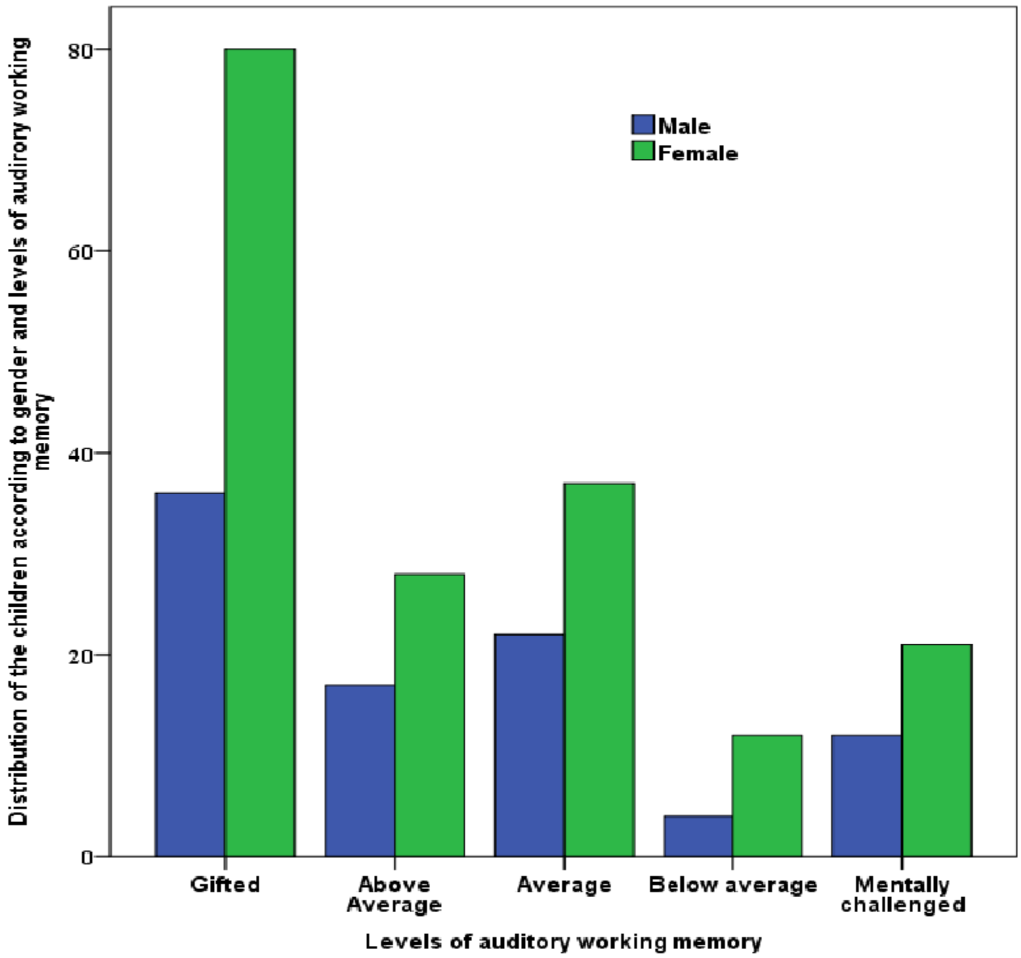

Figure 10. The levels of auditory working memory by gender

Levels of Auditory working memory by age: The 269 children had ages which ranged between 13-15 years of which the thirteen-year age category had 184 (68.4%) of whom eighty-three (45.1%) were gifted, 31 (16.8%) were above average, 42 (22.8%) were average, 13 (7.1%) and 15 (8.2%) were below average. For 58 (31.5%) fourteen-year olds twenty-three (39.6%) were gifted, ten (17.2%) were above average, eleven (19%) were average, two (3.4%) were below average, and twelve (20.7%) were average. The fifteen-year-olds were twenty-seven (9.3%) of whom ten (37%) were gifted, four (14.8%) were above average, six (22.2%) were average, while one (3.7%) were below average, and six (22.2%) were average, **Figure 11**. An ANOVA analysis indicated that there were insignificant differences in the AWM for between and within groups with F (2, 267) =.1, p=.905 at 95% CL.

Distribution of auditory working memory according to water fluoride in school areas: ***Levels of AWM and the school water fluoride:*** There were 116 (43.1%) gifted individuals attending the seven selected schools out of 269 while 45 (16.7%) were above average, 59 (21.9%) were average, 16 (6%) were below average, and 33 (7.4%) were mentally challenged.

Low water fluoride in the school and environs: In the schools whose water fluoride was between 0.5-1 mg/l there were 68(25.3%) out of the 269 children who attended the school and 34(35.3%) were gifted, seventeen (25%) were above average, 10 (14.7%) were average, while two (5.9%) were below average and five (23.5%) were mentally challenged, **Figure 12**.

Medium water fluoride in the school and environs: The one school who fluoride in the water and the neighbourhoods was medium (1.1-1.8 mg/l) had thirty-three (5.6%) children out of whom twenty-four (72.7%) were gifted, four (12.1%) were above average, four (12.1%) were average, and one (3.1%) was mentally challenged **Figure 12**.

High water fluoride in the school and environs: There were four schools whose water fluoride content, was above 1.6 mg /litre, and the total number of students attending the four schools was 168 (62.5%) out of 269. The children who were gifted in the high fluoride area were 58 (34.5%) out of the 168. Twenty four (14.3%) were above average, forty-five (26.8%) were average while 14 (8.3%) were below average and 27(16.1%) were mentally challenged, **Figure 12**.

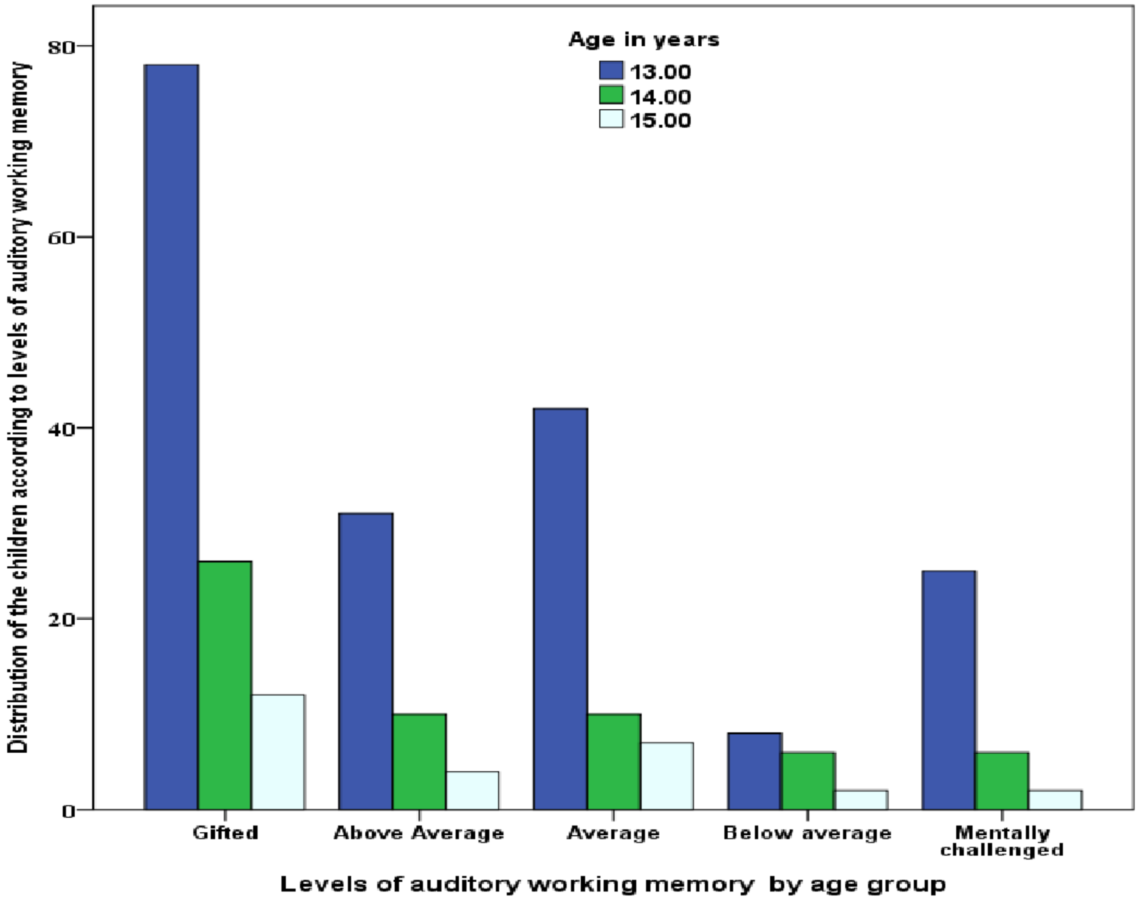

Figure 11. The levels of working memory by age

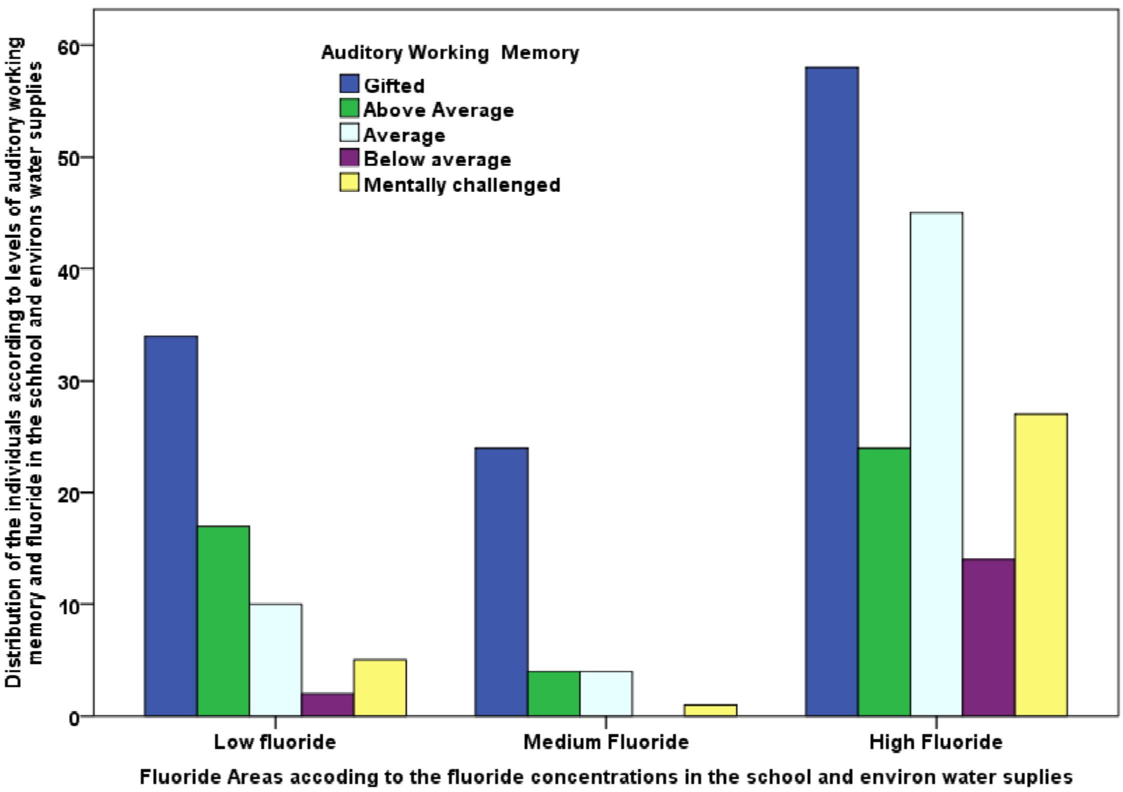

Figure 12. Distribution of the auditory working memory of the children according to the location of the school in the fluoride area

A comparison of the AWM of the children attending schools in the low fluoride area and that of those attending medium fluoride areas with Mann-Whitney U, 867.500, Z =-2.062 and p=0.39. Also, there significant differences in the auditory working memory of 68 (25.3%) children whose household water contained low fluoride concentrations (0-0.8mg/litre) when compared to the auditory working memory of 168 (62.5%) children whose household water contained fluoride concentrations of ≥ 1.6 mg/litre, a Mann-Whitney U=4261.5, Z-3.184 and p≤.001 at 95% CL. Similarly, a comparison of the auditory working memory between 33(16.4%) whose schools water supplies and the environs had medium fluoride and168 (83.6%) individuals whose water had high fluoride ≥6 mg/litre and significant differences were observed with a Mann-Whitney U=1548.5, Z=-4.194, p≤.001 at 95% CL.

The ANOVA analysis indicated significant differences in the auditory working memory within the children in the low, medium and high fluoride in school and environs water supply. Similarly, significant differences were observed between the children in the low, medium and high fluoride in the school and environs water supplies with F (1, 267) = 14.848, p≤.001 at 95% CL. A positive linear relationship was noted with a regression analysis where r=230, p≤.001 at 95% CL. The value for R^2= 0.059, an indication that fluoride concentration in the school and the environs water supplies contributed 5.3% towards auditory working memory with beta=.230, t= 3.853, p≤.001 at 95% CL.

Low, medium, and high fluoride in household water and the Levels of Auditory working memory: The Auditory working memory of the children were categorised according to the fluoride concentration in the water samples brought from their household as low medium, and high. There were 116 (%) who were gifted, 45 (%) were above average, 59 (%) were average, 16 (%) were below average, and 33 (%) were mentally challenged **Figure 13**.

Low (0-0.9 mg/litre) fluoride in household water: It was noted that 105 water samples had low fluoride which ranged between 0.0-0.9 mg/litre which corresponded to 105(39%) children attending schools in the low, medium 81 (30.1%) and 83 (30.9%) high fluoride areas. Out of the 105(%) children, sixty-four (61%) were gifted, 21(20%) were above average, 17(16.2%) were average, one (1%) was below average, and 2 (1.9%) were mentally challenged **Figure 13**.

Medium (1-1.5 mg/litre fluoride in household water: There were 81 household water samples whose fluoride concentration ranged between 1-1.5 mg/litre which corresponded to 81 (%) children attending schools in the medium areas. Out of the 81(%) children, 26 (32.1%) were gifted, 10 (12.3%) were above average, 24 (29.6%) were average, 7(8.6%) were below average, and 14 (17.3%) were mentally challenged, **Figure 13**.

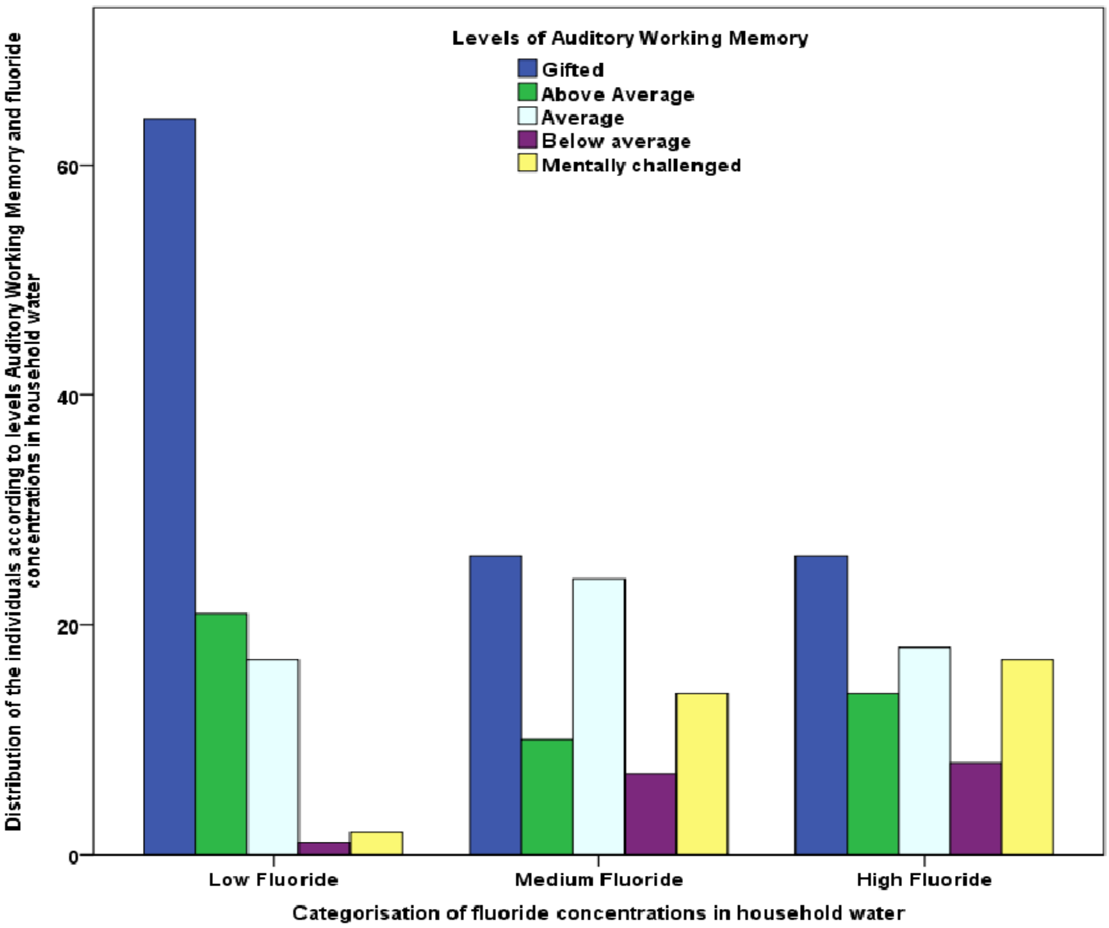

Figure 13. The Auditory working memory of the children according to household water categorisation

The household water fluoride concentration and auditory working memory high (1.6-15 mg/litre) fluoride in household water: The household water samples for 83 (30.9%) children had a fluoride content which ranged between ≥1.6mg/litre, and there were 26(31.3%) gifted children while 14 (16.9%) were above average, 18 (%) were average, 8 (21.7%) was below average, and 17 (20.5%) were intellectually challenged **Figure 13**.

The 105(39%) children who used the household water with low fluoride concentrations (0.0-0.9 mg/litre) had their auditory working memory compared with the auditory working memory of 81 (30.1%) individuals whose household water fluoride concentration was medium (1-1.6 mg/litre). Significant differences were observed with a Mann-Whitney U where U=3517, Z value= -2.091, p=0.037 95 % CL. Also, a comparison was made for the AWM of the children who used water with low fluoride concentration (0.0-0.8 mg/litre) with the AWM of 83 (30.9%) individuals whose domestic water contained high fluoride (≥1.6 mg/litre). There were significant differences in the AWM of the two groups with a Mann-Whitney U= 2580.5; Z value=-5.062 and p≤.001 95% CL. The AWM of the children who used water with medium fluoride (1-1.6 mg/litre) with the AWM of those whose household water had high fluoride (≥1.6 mg /litre) The differences in the auditory working memory was significant with a Mann-Whitney U=2524.5 and Z=-2.983, p≤ 0.003 at 95% CL.

An ANOVA analysis indicated that there were significant differences between the groups from low, medium and high fluoride concentration ranges in the household water. Also, differences which were significant were observed between the groups, thus low with a medium, low with high fluoride content and medium with high fluoride concentration ranges. The value for F (1, 267) = 33.935, p≤.001.

A linear analysis was performed between the fluoride concentration in the household water and the auditory working memory, and there was a strong and positive r= 0.336, while R^2=.113, F (1,267) = 33.935, p≤.001A significant difference in the AWM of children using the same fluoride concentration range, thus low, medium, and high. Also, there were differences in the AWM between children who used household water with low and medium; low and high, medium and high fluoride concentration ranges. Household water fluoride concentrations of low, medium, and high, contributed 11.3% towards the auditory working memory of the 269 children.

Subcategorisation of the fluoride concentration in household water samples and the auditory working memory: The fluoride concentration in the household water samples of the children was categorised into low, medium and high then compared with the AWM of the children and the fluoride levels of low, medium and high. The household water, the fluoride concentration had a strong negative association with a Pearson's R= -0.313, p≤.001 at 95% CL.

The mean auditory levels by the household water fluoride subcategorisation:

0-0.5mg/litre: The children were assessed according to the household water fluoride subcategories where children who used water with a fluoride content of between 0-0.5mg/litre were fifteen (5.6%) of whom three were gifted, one was above average four were average, four were broken average, and three were mentally challenged **Figure 14**.

A comparison of the auditory working memory for children using concentrations of fluoride in household water of 0-0.5mg/litre with the AWM of the children using fluoride concentrations. The concentrations were as follows 0-0.5mg/litre vs 0.5-0.8mg/litre, 0.8-1mg/litre, 1-1.8mg/litre, 1.8-2.5 g/litre, 2.5-3 mg/litre; 3-6mg/litre and ≥6 mg/litre of fluoride. The 15(5.6%) children who used water with a fluoride content of 0-0.5mg/ litre had their auditory working memory compared with that of 52(19.3%) individuals whose water had 0.5-0.8 mg/litre fluoride with a Mann-Whitney U. However, the difference was insignificant where U=332.5, Z=-.892, P=.373 at 95% CL.

Thirty-nine (14.1%) individuals whose household water fluoride in the range of 1-1.8 mg/litre had their AWM compared to that of 15(5.6%) individuals using a Mann-Whitney U. The differences were insignificant with the Mann U value =213.5, Z=-1.523, p=.128 at 95% CL.

Forty-one (15.2%) adolescents who used household water with a fluoride content range of 1-1.8 mg/litre had their AWM compared with that of 15(5.6%) individuals whose water fluoride content ranged between 0-0.5 mg/litre, and there was a significant difference with a Mann-Whitney U. The Mann-Whitney U value=186. Z=-2.373, p=.018 at 95% CL.

Forty-four (%) individuals using water with a fluoride 1.8-2.5 mg/litre had significant differences in their AWM compared with 15(5.6%) individuals whose water fluoride content ranged between 0-0.5 mg/litre. The Mann Whitney U value =163.000, Z=-3.044, p=0.002 at 95% CL.

Twenty four (8.9%) individuals whose household water fluoride concentration was 2.5-3 mg/litre had their AWM compared with that of 15(5.6%) adolescents whose water fluoride content ranged between 0-0.5 mg/litre. A significant difference in the AWM was observed between the two groups with a Mann-Whitney U analysis, where the U value =66.500, Z=-3.396, P≤.001 at 95% CL.

Sixteen (5.9%) adolescents using water with a fluoride content of 3.0-6 mg/litre had their AWM compared with that of individuals using water with 0-0.5mg/litre of fluoride. However insignificant differences were observed between the two groups with a Mann- Whitney U= 73, Z=-1.991, p=0.047 CL.

Thirty-nine (14.5%) adolescents whose household water contained ≥6mg/litre had their AWM compared with that of the individuals whose water fluoride was 0-0.5mg/litre and significant differences were observed. The Mann-Whitney U =190.500, Z=-2.105, P.≤035, AT 95% CL.

0.5-0.8 mg/litre of fluoride in household water: There were fifty-two (19.3%) individuals whose household water contained fluoride concentrations in the range of 0.5-0.8 mg/litre. Out of the 52, thirty eighty (73.1%) had a gifted

AWM, nine (17.3%) were above average, five (9.6%) were average, and none of the children in this group was below average or mentally challenged **Figure 14**.

Fifty-two (19.3%) individuals whose household water had 0.5-0.8 mg/litre fluoride had their AWM compared with AWM of 38(14.1%) individuals whose household water fluoride in the range of 0.8-1 mg/litre. The Mann Whitney U and that there were significant differences with U= 645.5, Z= -3.187, p≤.001 at 95% CL.

Forty-one (15.2%)adolescents who used household water with a fluoride content range of 1-1.8 mg/litre had their AWM compared with that of 52 (19.3%) individuals whose household water had 0.5-0.8 mg/litre fluoride. The Mann Whitney U yielded U=558.5, Z=-4.353, p≤.001 at 95% CL.

Forty-four (16.4%) individuals using water with a fluoride 1.8-2.5 mg/litre had significant differences in their AWM compared with52 (19.3%) individuals whose household water had 0.5-0.8 mg/litre of fluoride. The Mann Whitney U values were, U=492.500, Z=-5.229, p≤.001 at 95% CL.

Twenty four (8.9%)Individuals whose household water fluoride concentration was 2.5-3 mg/litre had their AWM compared with the AWM of 52(19.3%) individuals whose water had 0.5-0.8 mg/litre fluoride. The Mann-Whitney U where U=187.500; Z=-5.380, p≤.001 at 95% CL.

Sixteen (5.9%) individuals whose household water fluoride concentration was **3**.0-6 mg/litre had their AWM compared with that of the auditory working memory of 52(19.3%) individuals whose household water had 0.5-0.8 mg/litre fluoride. Significant differences were noted with a Mann- Whitney U, where the U value=217.5, Z=-3.342, p≤.001 at 95% CL.

Thirty-nine (14.5%) adolescents whose household water contained ≥6mg/litre had their AWM compared with the AWM of 52(19.3%) individuals whose household water had 0.5-0.8 mg/litre fluoride. The differences were significant with a Mann Whitney U=593, Z=-3.813, p≤.001 at 95% CL.

0.8-1.0 mg/litre of fluoride in household water: The children whose household water fluoride concentration ranged between 0.8-1.0 mg/litre were thirty eighty (14.1%) out of 269. There was one (2.6%) was a gifted individual, eight (21.1%) were above average, six (15.8%) were average, while three (7.8%) were below average and six (15.8%) were mentally challenged Figure 13.

The AWM of 38(14.1%) individuals whose household water fluoride in the range of 0.8-1 mg/litre was compared with the AWM forty-one (15.2%) adolescents who used household water with a fluoride content range of 1-1.8 mg/litre. The Mann Whitney U revealed that there were insignificant differences in the AWM of the two groups with the value for U=641.5, Z=-1.41, p=.159.

Forty-four (16.4%) individuals using water with a fluoride 1.8-2.5 mg/litre had significant differences in their AWM compared with the AWM of 38(14.1%) individuals whose household water fluoride in the range of 0.8-1 mg/litre using the Mann Whitney U. The U value = 567.50, Z= -2.593, p≤0.010 at 95% CL.

Twenty four (8.9%) individuals whose household water fluoride concentration was 2.5-3 mg/litre had their AWM compared with the AWM of 38(14.1%) individuals whose household water fluoride in the range of 0.8-1 mg/litre with a Mann Whitney U. The differences in the AWM had a U value= 255.500, Z=-2.995, p≤0.003.

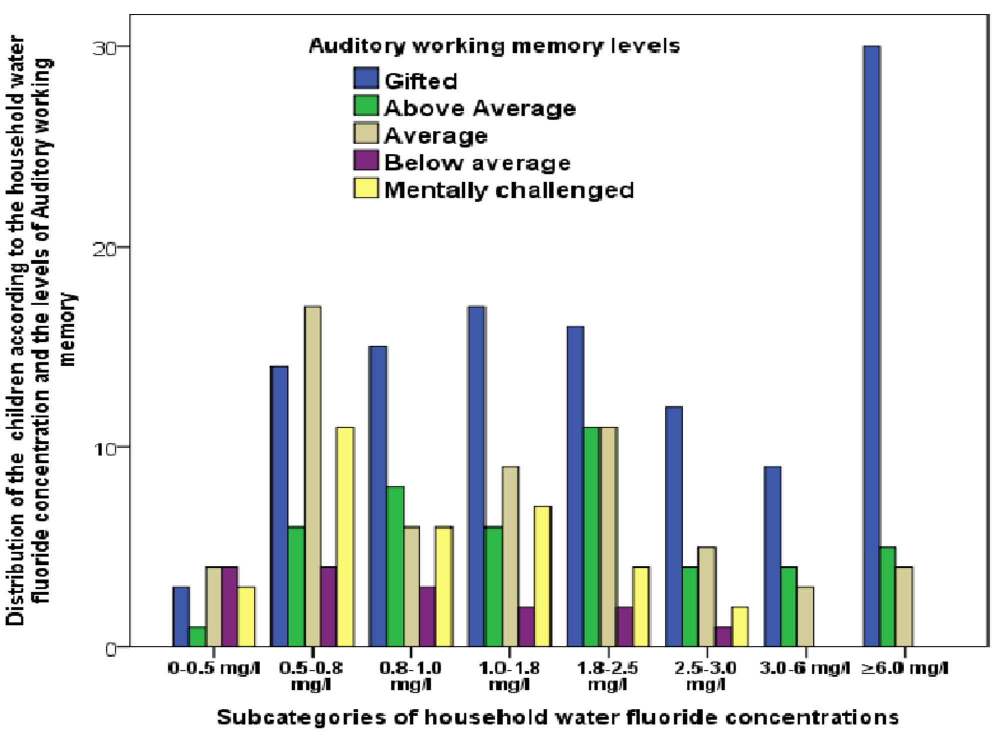

Figure 14. Distribution of the children based on fluoride concentrations in household water and the auditory working memory

Sixteen(5.9%) individuals whose household water fluoride concentration was **3**.0-6 mg/litre had their AWM compared with that of the auditory working memory of 38(14.1%) individuals whose household water fluoride in the range of 0.8-1 mg/litre using a Mann Whitney U. The differences in the AWM were nonsignificant with the value for U=255.5, Z=-.963, p=.336 at 95% CL.

Thirty-nine (14.5%) adolescents whose household water contained ≥6mg/litre had their AWM compared with the AWM of 38(14.1%) individuals whose household water fluoride in the range of 0.8-1 mg/litre using a Mann Whitney U. The differences in the AWM were insignificant with the U value as 631.5, Z=-1.170, p=.242 at 95% CL.

1.0-1.8 mg per litre fluoride in household water with a fluoride range of 1.0-1.8 mg per litre was used by forty-one (15.2%) children of whom 17 (34.1%) were gifted, six (14.6%) were above average, nine (22%) were average, while two (4.9%) were below average and seven (17.1%) mentally challenged, **Figure 14**.

The AWM of forty-one (15.2%) adolescents who used household water with a fluoride content range of 1-1.8 mg/litre was compared with the AWM of forty-four (16.4%) individuals using water with a fluoride 1.8-2.5 mg/litre. The differences in the AWM was insignificant with a Mann Whitney U, where U=763.5, Z=-1.261, p=.207 at 95% CL.

Twenty four (8.9%) individuals whose household water fluoride concentration was 2.5-3 mg/litre had their AWM compared with the AWM of forty-one (15.2%) adolescents who used household water with a fluoride content range of 1-1.8 mg/litre. The differences in the AWM were insignificant with a Mann Whitney U=366.5, Z=-1.756, p=079 at 95% CL.

Sixteen (5.9%) individuals whose household water fluoride concentration was **3**.0-6 mg/litre had their AWM compared with that of the auditory working memory of forty-one (15.2%) adolescents who used household water with a fluoride content range of 1-1.8 mg/litre. Insignificant differences in the AWM was indicated with a Mann-Whitney U where U=326.5, Z=-.028, p=.978 at 95% CL.

Thirty-nine (14.5%) adolescents whose household water contained ≥6mg/litre had their AWM compared with the AWM of forty-one (15.2%) adolescents who used household water with a fluoride content range of 1-1.8 mg/litre. Nonsignificant differences were observed in the AWM of the two groups, with a Mann_whitney U, where the U values =795.0, Z=-.045, p=.964 at 95% CL.

1.8-2.5 mg/litre fluoride in household water: Forty-four (16.4%) children whose household water samples had a fluoride concentration which ranged between 1.8-2.5 mg/litre of fluoride had 16 (35.4%) out of 44 were gifted individuals, 11(25%) adolescents had an AWM of above average, 11(25%) had an auditory working memory of average while two (04.5%) their AWM was below average, and 4(9.1%) were mentally challenged Figure 13. A comparison was made of the AWM of the children who used water with 1.8-2.5 mg/litre with the AWM of children who used higher fluoride concentrations in their household water. Twenty four (8.9%) individuals whose household water fluoride concentration was 2.5-3 mg/litre had their AWM compared with the AWM of forty-four (16.4%) individuals using water with a fluoride 1.8-2.5 mg/litre. Insignificant differences were observed with a Mann_whitney U, where the U values =483.5, Z=-.588, p=.556 at 95% CL Negligible differences were noted when sixteen (5.9%) individuals whose household water fluoride concentration was **3**.0-6 mg/litre had their AWM compared with that of the auditory working memory of forty-four (16.4%) individuals using water with a fluoride 1.8-2.5 mg/ litre. The Mann- Whitney U values were U=302, Z=-.861, p=.389 at 95% CL.

Forty-four (16.4%) individuals using water with a fluoride 1.8-2.5 mg/litre had significant differences in their AWM compared with the AWM of thirty-nine (14.5%) adolescents whose household water contained ≥6mg/litre.

2.5-3.0 mg/litre fluoride in household water: Twenty-four (8.9%) adolescents out of whom 12 (50%) were gifted, five (20%) were above average, four (16.6%) were average while one (4.1%) was below average and two (8.3%) were mentally challenged, **Figure 14**.

Twenty four (8.9%) individuals whose household water fluoride concentration was 2.5-3 mg/litre had their AWM compared with the AWM of Sixteen(5.9%) individuals whose household water fluoride concentration was **3**.0-6 mg/litre. Nonsignificant differences in the AWM of the children in the two different fluoride concentration ranges were insignificant with A Mann-Whitney U, where U=144.5, Z=-1.341, p=.180.

Thirty-nine (14.5%) adolescents whose household water contained ≥6mg/litre had their AWM compared with the AWM of twenty-four (8.9%) individuals whose household water fluoride concentration was 2.5-3 mg/litre. However, the differences were insignificant with a Mann-Whitney U, where U= 0.00, Z=-1.429, p=.153.

3.0-6 mg/litre fluoride in household water: In the 3-6 mg/litre water fluoride category had 16 individuals out of whom 9(%) were gifted, 4(%) were above average, and 3(%) were average. However, in this category, there were no below average or mentally challenged individuals. Sixteen(5.9%) individuals whose household water fluoride concentration was **3**.0-6 mg/litre had their AWM compared with that of the auditory working memory of Thirty-nine (14.5%) adolescents whose household water contained ≥6mg/litre. A Mann-Whitney U showered insignificant differences with U=310, Z=-.039, p=.969 at 95% CL.

Fluoride concentration in household water ≥ 6 mg/litre: The water with a fluoride concentration of ≥6 mg/litre had thirty-nine (14.5%) were gifted individuals, 5(12.8%) were above average, 4(10.3%) were average. However, there were no individuals who were below average and mentally challenged.

4. Discussion

The study population of female participants was high. This difference between the genders may be explained by the willingness of the females to participate in research than the males through the external support of supplying sanitary towel initiatives from both the Ministry of Education in Kenya and Non-Profit organisations operating in the area in the blight of a girl child. The low enrolment of the boys supports a report on the status of the boy child in Kenya by the National Gender and Equality Commission 2015 which gave a perception that 92% of the respondents believed that the boy child is lagging in the gender equality agenda [14]. This difference in higher numbers of females being recruited in a study can be associated with a higher rate of school drop out by the boys. The finding also affirms the status of the boy child in Kenya by the National Gender and Equality Commission 2015 which showed higher dropout rates for the boys than the girls at class four and five while at enrolment in schools in the lower primary; boys are equal to or even more than the girls.

Fluoride is essential for the development of the child and should, therefore, be supplied in small amounts [15]. Excessive fluoride ingestion has both visible and invisible effects [15] [16]. This study investigated the difference in AWM subtest of WISC-V in children using low (≤1.0mg/l) water fluoride, medium (≥1.1≤2.0mg/l) and high (≥2.1mg/l) water fluoride living in Kajiado County which is in the former Rift Valley Province of Kenya. Water drawn from the sources of water supply to the participants detected no lead, arsenic or copper. The heavy metals in the drinking water may affect intelligence development of children.

The study demonstrates that the mean AWM on WISC-V test of adolescents in high (≥2.1mg/l) water fluoride areas and high (≥2.1mg/l) household water fluoride was significantly lower than children in both low (≤1.0mg/l) water fluoride areas and low (≤1.0mg/l) household water fluoride. Considering that most of the confounders were adjusted for, the difference in AWM may be potential because of the high fluoride in the school water supplies and the high fluoride content in the household. The low AWM in children using water with high fluoride concentrations is a challenge to the Kenya government as there is inadequate quality surface water and as the peri-urban satellite towns are set up more children will be exposed to high fluoride from underground water sources. Secondly in the Kenya's education system children are not assessed for their cognitive abilities before they are placed in a class. Such children may perform poorly in school where the teachers may fail to notice the cause of the poor performance and there is a need that children in high fluoride areas be assessed to determine their cognitive abilities.

The current study found a higher proportion of children with high AWM in low household water fluoride than in high water fluoride areas. The finding in the current study is contrary to what a study in India reported higher fluoride levels resulted in higher levels of intelligence [17]. Memory is defined merely as the ability to retain information over time. Auditory memory is the ability to take orally presented information, process it, store it and be able to recall what was heard [18]. This cognitive functioning requires one to be attentive, record, process, store and retrieve the information when needed. Poor AWM results when children can't record, process, store or retrieve the information that was exposed to, this has negative consequences on learning. Children with low AWL find it challenging to pay attention and follow instructions. AWM plays a critical role in literacy as it has a direct impact on reading and writing, spelling and mathematics skills. According to Cyndi Ringoean, a neuro-developmentalist, a child with poor AWM cannot learn using the phonics method [19]. When even doing self-reading, listening and processing the information when the child needs to do silent reading a good AWM to recall what was read. Addie Cusimano also opines that AWM is overlooked as a learning skill deficiency and he found severe deficiencies in children with hyperactivity and or attention deficit disorders [19]. Working memory is strongly correlated to intelligence in adults and children hence those performing better on working memory tasks have also shown a tendency to be better on the intelligence task [20] [21]. Several animal studies have tried to explain the possible mechanisms of neurotoxicity of fluoride [22] [23]. Fluoride when ingested through the child's diet or crosses the placenta, its retained in the body about 80-90% in children and 60% in adults [15] [24]. Its absorbed into the bloodstream and forms complexes which are lipid soluble and can cross the blood-brain- barrier hence accumulating in the cerebral tissues [16]. This complexes then affect the development of the CNS by different mechanisms, e.g. inhibition of glutamate transporters, free radical generation and inhibition of mitochondrial energy and antioxidant enzymes [25]. This alteration in the structure and function in the CNS especially during the 1st eight years of life and also during foetal growth may lead to cognitive dysfunction, intellectual deficits and learning difficulties [22] [25]. Fluoride has also been shown to interfere with thyroid gland activity leading to an adverse effect on the development of the brain and function in children [26].

Cognitive development is determined by genetic and environmental factors [27]. The regression analysis in this study showed that high fluoride content level in household water supply significantly affected AWM. That other factors like age, gender, child's and parents' level of education and income did not. The result is in agreement with the study by Seraj B and Xiang Q [6] [28]. The low AWM for the children using high fluoride in an agreement with a study where a systematic review and a meta-analysis that showed reported in the literature that children who used water with high fluoride had consistently low IQ which was an indication of fluoride neurotoxicity effects [29]. A recent study in Una, Himachal, Pradesh India where the fluoride in the water supplies was more than 0.5ppm and reported insignificant association between the low intelligence level with the high fluoride in the water. The challenge we observed in our current study was that there were children from the low fluoride area who attended schools supplied with high fluoride. A finding which we did not document in the current study is that 86% of the children carried water to school and this masked the relationship with water. However, when each child was correlated with the fluoride in the water which they regularly carry to school there were strong associations between the household water and the children's AWM. At 0.5mg/liter there was a strong association between the children's AWM and the subcategories of fluoride concentration as we found that the children had varied sources of for water and the fluoride concentration in the household water varied according to the source [30]. The study population recruited respondents from the semi-urban homogeneous community in Kajiado who attended public schools reducing the effect of environmental factors [6]. However, complete elimination of both environmental and genetic factors is near impossible [6]. The water fluoride content in both area and the household were used as an indicator of the child's fluoride exposure. The study may support the hypothesis that excess fluoride in drinking water is neurotoxic. Therefore, there is a need for constant and close monitoring and regulation of fluoride levels in water supplied to the population especially in endemic fluorosis areas and also the implementation of public health policy to reduce the exposure to high fluoride in water.

Study Limitations

It was a cross-sectional descriptive study, this may have flaws, and it was difficult to control the children using low fluoride in household water from attending a school in a high fluoride area. Similarly, those from the high fluoride household water may have participated at the low fluoride school. The study did not recruit the adolescents who had dropped out to assess the AWM; previous studies have shown that poor academic achievement is correlated with high school dropout and low school enrolment.

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REFERENCES

[1] Jha SK, Nayak AK, Sharma YK. Potential fluoride contamination in the drinking water of Marks Nagar, Unnao district, Uttar Pradesh, India. Environ Geochem Health. 2010.

[2] Rango T, Vengosh A, Jeuland M, Tekle-Haimanot R, Weinthal E, Kravchenko J, et al. Fluoride exposure from groundwater as reflected by urinary fluoride and children's dental fluorosis in the Main Ethiopian Rift Valley. Sci Total Environ. 2014.

[3] Kim MJ, Kim HN, Jun EJ, Ha JE, Han DH, Kim JB. Association between estimated fluoride intake and dental caries prevalence among 5-year-old children in Korea. BMC Oral Health. 2015.

[4] Baskaradoss JK, Clement RB, Narayanan A. Prevalence of dental fluorosis and associated risk factors in 11-15-year-old school children of Kanyakumari District, Tamilnadu, India: a cross-sectional survey. Indian J Dent Res. 2008.

[5] Opinya GN, Imalingat B. Skeletal and dental fluorosis: two case reports. East Afr Med J. 1991.

[6] Seraj B, Shahrabi M, Shadfar M, Ahmadi R, Fallahzadeh M, Eslamlu HF, et al. Effect of high water fluoride concentration on the intellectual development of children in makoo/iran. J Dent (Tehran). 2012.

[7] Mullenix PJ, Denbesten PK, Schunior A, Kernan WJ. Neurotoxicity of sodium fluoride in rats. Neurotoxicol Teratol. 1995.

[8] Yu Y, Yang W, Dong Z, Wan C, Zhang J, Liu J, et al. Neurotransmitter and receptor changes in the brains of fetuses from areas of endemic fluorosis. Fluoride. 2008.

[9] Yazdi SM, Sharifian A, Dehghani-Beshne M, Momeni VR, Aminian O. Effects of fluoride on psychomotor performance and memory of aluminium potroom workers. Fluoride. 2011.

[10] Jiang S, Su J, Yao S, Zhang Y, Cao F, Wang F, et al. Fluoride and arsenic exposure impairs learning and memory and decreases mGluR5 expression in the hippocampus and cortex in rats. PLoS One. 2014.

[11] Katunge Emily. Dental caries and gingivitis by tooth type among 13–15-year-olds with varying severity of fluorosis Dissertation 78-79.

[12] Makhanu M, Opinya G and Mutave R.J.: Dental fluorosis, caries experience and snack intake of 13-15-year olds in Kenya East African Medical Journal Vol. 85 No. 3 March 2009.

[13] Wechsler D. Wechsler intelligence scale for children–Fourth Edition (WISC-IV). San Antonio, TX Psychol Corp. 2003.

[14] National Gender and Equality Commission. The status of the boy child in Kenya A Report of emerging perception on the exclusion of the boy child in the gender equality agenda. 2015.

[15] Fawell J, Bailey K, Chilton J, Dahi E, Fewtrell L, Magara Y. Fluoride in Drinking-water. World Health Organization. 2006.

[16] Vani ML, Reddy KP. Effects of fluoride accumulation on some enzymes of brain and gastrocnemius muscle of mice. Fluoride. 2000.

[17] Trivedi MH, Verma RJ, Chinoy NJ, Patel RS, Sathawara NG. Effect of high fluoride water on intelligence of school children in India. Fluoride. 2007.

[18] Rönnberg N, Rudner M, Lunner T, Stenfelt S. Memory

performance on the Auditory Inference Span Test is independent of background noise type for young adults with normal hearing at high speech intelligibility. Front Psychol. 2014.

[19] Tutor eduboX online. Cyndi Ringoean, a neuro-development alist, a child with poor AWM can't learn using the phonics. Edubox online tutor.

[20] Oberauer K, Wilhelm O, Schulze R, Süß HM. Working memory and intelligence -Their correlation and their relation: Comment on Ackerman, Beier, and Boyle (2005). Psychological Bulletin. 2005.

[21] Cowan N, Alloway T. Development of working memory in childhood. Dev Mem infancy Child (2nd ed). 2009.

[22] Ge Y, Ning H, Feng C, Wang H, Yan X, Wang S, et al. Apoptosis in brain cells of offspring rats exposed to high fluoride and low iodine. Fluoride. 2006.

[23] Chirumari K, Reddy PK. Dose-dependent effects of fluoride on neurochemical milieu in the hippocampus and neocortex of rat brain. Fluoride. 2007.

[24] Suneetha M, Sundar BS, Ravindhranath K. Groundwater quality status concerning fluoride contamination in Vinukonda Mandal, Guntur District, Andhra Pradesh, India and defluoridation with activated carbons. Int J ChemTech Res. 2015.

[25] Blaylock RL. Excitotoxicity: A possible central mechanism in fluoride neurotoxicity. Fluoride. 2004.

[26] Susheela AK, Bhatnagar M, Vig K, Mondal NK. Excess fluoride ingestion and thyroid hormone derangements in children living in Delhi, India. Fluoride. 2005.

[27] Oommen, Arun (Consultant Neurosurgeon LH& RC in I. Factors Influencing Intelligence Quotient. J Neurol Stroke. 2014.

[28] Xiang Q, Liang Y, Chen L, Wang C, Chen B, Chen X, et al. Effect of fluoride in drinking water on children's intelligence. Fluoride. 2003.

[29] Anna L. et. al.; Developmental Fluoride Neurotoxicity: A Systematic Review and Meta-Analysis Environ Health Perspect 120:1362–1368 (2012). http://dx.doi.org/10.1289/ehp.1104912 [Online 20 July 2012].

[30] SHARMA, Piyush et al. Does fluorosis affect the intelligence profile of children? A cross sectional analysis of school children of district Una, Himachal Pradesh, India. International Journal Of Community Medicine And Public Health, [S.l.], v. 5, n. 3, p. 1047-1053, feb. 2018. ISSN 2394-6040. http://www.ijcmph.com/index.php/ijcmph/article/view/2453. Date accessed: 25 sep. 2018. doi:http://dx.doi.org/10.18203/2394-6040.ijcmph20180759.