Original Article

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Dentistry Section

Relationship Between Dental Fluorosis and Intelligence Quotient of School Going Children In and Around Lucknow District: A Cross-Sectional Study

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ABSTRACT

Background: Fluoridation of drinking water, despite being regarded as one of the top ten public health achievements of the twentieth century, has remained a much debated concept. Various studies on animals and aborted human fetuses have confirmed that excessive fluoride intake during infancy and early childhood, causes a number of irreversible structural and functional changes in the CNS leading to memory, learning and intellectual deficits.

Aim: To compare the IQ levels of school children of two different locations, having different fluoride levels in water, and to establish a relationship between fluoride levels, prevalence of fluorosis and its effect on IQ levels.

Materials and Methods: A cross–sectional study was conducted among 429 children aged 6 – 12 years, selected by stratified random sampling from two different areas with different levels of fluoride in drinking water in and around Lucknow district. Dental fluorosis was measured using Dean's Fluorosis Index. Intelligence Quotient was measured using Raven's Coloured Progressive Matrices (1998 edition).

Results: Majority of the fluorosis free children (76.3%) had an IQ grade 2 (definitely above the average). Majority of the children suffering from very mild and mild dental fluorosis were found to have IQ grade 3 (Intellectually average). Children with moderate cases of dental fluorosis were found to have IQ grade 4 (Definitely below average). Only 5 children with severe fluorosis were included in the study and they all were found to have an IQ grade 5. Hence, a trend of increase in the IQ grade (decrease in intellectual capacity) was observed indicating a strong correlation between fluorosis grade and IQ grade.

Conclusion: Findings of this study suggest that the overall IQ of the children exposed to high fluoride levels in drinking water and hence suffering from dental fluorosis were significantly lower than those of the low fluoride area.

Keywords: Cognitive dysfunction, Dean's fluorosis index, Intellectual deficits, Neurotoxicity, Raven's coloured progressive matrices

INTRODUCTION

Water is one of the most valuable natural resources for sustaining life. Though, its suitability to be used for domestic, industrial or agricultural purposes is majorly decided by its chemical composition. Fluoride is a valuable component of water when it is present in small quantity. However, in excess amount it may produce several health problems such as dental fluorosis, skeletal fluorosis and various neurological manifestations [1-3].

Fluoride ion in drinking water is known to have beneficial effects on teeth at low concentrations [4]. Fluoride has been added to the public water supplies to reduce the incidence of dental caries [5]. Dean and others [6] determined 1ppm to be the optimum level of fluoridation for caries reduction while minimizing levels of dental fluorosis [7].

In India fluorosis was first reported by Shortt et al., in Nellore district of Madras state [8]. An estimated 62 million people, including 6 million children below the age of 14 years, suffer from fluorosis in India, due to consumption of fluoridated water [9].

Fluoride can attack mercilessly, against any age group, but its effects are especially harmful to pregnant women & developing children [1,10]. Its adverse effects are irreversible, ranging from mild dental fluorosis to crippling skeletal fluorosis [1,2]. The severity of fluorosis depends upon the concentration of fluoride in the drinking water, daily intake, duration of exposure and climatic conditions [11].

Fluoride ingestion in excess amounts also has detrimental neurological effects. Fluoride has the ability to form lipid soluble complexes which can penetrate the foetal blood brain barrier and accumulate in cerebral tissues before birth thereby affecting intelligence [12]. Some studies reveal that fluoride can induce changes in the brain's physical structure and biochemistry which affect the mental development of children during cognitive processes, such as learning and memory specifically in the foetal period and first 8 years of life [1,10,13,14].

In the light of above reports, the present study is aimed at investigating a link between the intelligence ability and level of fluoride exposure of the children by examining the intelligence quotient (IQ) scores and dental fluorosis status of the children falling in the age group of 6-11 years from areas in and around Lucknow district with low (0.19 ppm) and high (2.41 ppm) concentrations of fluoride in drinking water.

MATERIALS AND METHODS

Data collection: Ethical Clearance and Informed Consent: This study was conducted under the surveillance of Department of Pedodontics and Preventive Dentistry in Saraswati Dental College and Hospital, Lucknow. The study protocol was approved by the ethical committee of Saraswati Dental College. Informed consent was obtained from the parents and respective school authorities.

Study Design: The present study was conducted to compare the IQ levels of children aged 6-11 years, of two different locations having different fluoride levels in water and to establish a relationship between fluoride levels, prevalence of fluorosis and its effect on IQ levels. The duration of the study was 6 months and the sample collection was carried out during the school hours.

Study Population: A cross-sectional study was carried out among 6-11-year-old school going children in high fluoride area of Asoha block in district Unnao & low fluoride area of Tiwariganj block in district Lucknow of Uttar Pradesh, India. A total of 429 children fulfilling the inclusion criteria, were selected through stratified random sampling and enrolled in the study. Out of these 429 children, 214 (49.9%) belonged to Tiwariganj where fluoride levels were found to be 0.19 ppm and rest 215 (50.1%) belonged to Unnao where fluoride levels were found to be 2.41 ppm.

Inclusion Criteria: Children included in the study were 6-11 years of age and had –

- Similar socio-economic status.
- Normal birth history.
- Continuous residents of the study area since birth and drinking water from the same source.
- No history of chronic illness, trauma to the head and not on any medication.

Exclusion Criteria: Children excluded from the study had –

- History of trauma to the head or other neurological disorder.
- Any congenital or acquired diseases affecting intelligence.
- Children who had a change in the source of drinking water since birth.
- Severe extrinsic stains on their teeth due to which assessment of dental fluorosis status was not possible.

Collection and analysis of water sample: Prior to the instigation of the study, the selection of the areas for the study was done in accordance with the findings of the fluoride mapping survey conducted by Srivastava et al., in villages of Uttar Pradesh [15]. The areas chosen were village Moradabad in district Barabanki, villages Kandharapur and Gosainkhera of Asoha block and Maheshkhera of Sumerpur block in district Unnao and village Tiwariganj located in district Lucknow. Water samples were collected from bore-well and stored in sterilized plastic cans of 2 litres capacity each. After collection of water samples, proper labelling of bottles was done depicting the area of water sample from where it was collected and within 24 hours of collection of samples, they were sent to the laboratory for the estimation of fluoride using IS 3025 (Part 60): 2008 (Ion Selective Electrode Method) [16].

Based on the water fluoride analysis reports, areas finally selected for the study were - Tiwariganj block in District Lucknow (0.19ppm) as the low fluoride area and Asoha block in District Unnao (2.41ppm) as the high fluoride area.

Selection of study area: The areas selected were rural areas having similar climatic conditions, with majority of the population belonging to lower socio-economic status with similar standards of living, quality of education, medical facilities and cultural status. The children included in the study had comparable physical health and nutrition. Each of the two selected areas had only one government secondary school. All the children studying in these schools were residing within a radius of 1-2 kms.

Study Tools: Data was collected by clinical examination for assessment of dental fluorosis using Dean's fluorosis index [17] and the IQ levels were tested by means of Raven's Coloured Progressive Matrices (1998 edition) [18]. A self-administered questionnaire proforma was attached consisting of personal information, source of drinking water and duration of use of present source of drinking water.

Clinical examination for the assessment of dental fluorosis – The assessment of severity and grades of dental fluorosis was done [Table/Fig-1] in accordance with the Dean's Fluorosis Index Original Criteria "1934" given by Trendley H Dean [7]. The scores were given to individuals after examining all the teeth present. Recording was based on the two most affected teeth. However, if the two teeth were not equally affected, the score for the less affected tooth was recorded. When teeth were being scored, examination was done starting from the higher end of the index "severe" and each score was eliminated until the final condition was reached. In case of doubt, the lower score was recorded.

Assessment of IQ levels: The Raven's coloured progressive matrices 1998 edition [18] (RCPM) was used to assess the IQ levels of each child at the age of 6-11 years. This is a validated test for basic cognitive abilities and is widely used to evaluate the normal brain functions [19,20]. The RCPM consists of 36 problems in three sets of twelve: A, Ab and B. It is designed for use amongst young children and old people, for anthropological studies, and for clinical work. It is a non-verbal questionnaire, examples of the problems contain a matrix of geometrical design, with a part removed. The child has to select the missing cell from six given alternatives. Each child was given a questionnaire and was asked to answer all the questions in the specifically designed answer paper. They were allotted a time limit of 30 minutes according to the specification of the test manual. The results obtained were converted into percentile and then overall score in individual assessment was graded as per the guidelines of Raven's Coloured Progressive Matrices manual [Table/Fig-2].

Fluorosis Level	Score
Normal	0
Questionable	0.5
Very mild	1.0
Mild	2.0
Moderate	3.0
Moderately severe	3.0
Severe	4.0

[Table/Fig-1]: Criterion for Dean's fluorosis index

Grade I:	"Intellectually superior", if a score lies at or above 95th percentile for people of that age group.
Grade II:	"Definitely above the average in intellectual capacity", if a score lies at or above the 75th percentile.
Grade III:	"Intellectually average", if a score lies between the 25th and 75th percentile.
Grade IV:	"Definitely below average in intellectual capacity" if a score lies at or below the 25th percentile.
Grade V:	"Intellectually impaired", if a score lies at or below the 5th percentile for that age group.

[Table/Fig-2]: Grading criterion for IQ scores according to Raven's Coloured Progressive Matrices manual

Standardization of the recording procedure : The examination of all subjects was carried out by a single examiner (i.e. the investigator himself) and recording of the scores was also done by the same individual. Calibration of the examiner was done before the study was conducted as well as during the study by doing duplicate examination of 5% (1 in 20) of the total population.

STATISTICAL ANALYSIS

The statistical analysis was done using SPSS (Statistical Package for Social Sciences) Version 15.0 statistical Analysis Software. The statistical tools used include – Mean, Standard Deviation, Chi-square test, ANOVA and Post-Hoc Analysis. Spearman's rank correlation was used for measuring the relationship between the two variables.

RESULTS

[Table/Fig-3] shows the demographic profile of children at two locations, including the number of children and their distribution according to age and gender. Females were found to be higher in the high fluoride area as compared to the low fluoride area and

S.N.	Characteristic	Tiwariganj (n=214)		Unnao (n=215)		Total (n=429)		Significance of difference	
		No.	%	No.	%	No.	%	χ^2	p
1.	**Gender**								
	Female	87	40.7	115	53.5	202	47.1	7.090	0.008
	Male	127	59.3	100	46.5	227	52.9		
2.	**Age**								
	6	0	0.0	2	0.9	2	0.5	5.423	0.366
	7	24	11.2	32	14.9	56	13.1		
	8	53	24.8	50	23.3	103	24.0		
	9	43	20.1	52	24.2	95	22.1		
	10	55	25.7	45	20.9	100	23.3		
	11	39	18.2	34	15.8	73	17.0		
Mean Age ± SD		9.15±1.29		8.97±1.33		9.06±1.31		p=0.151	

[Table/Fig-3]: Comparison of demographic profile of children at two locations according to gender and age

IQ Grade	Tiwariganj (n=214)		Unnao (n=215)		Total (n=429)	
	No.	%	No.	%	No.	%
1	6	2.8	0	0.0	6	1.4
2	160	74.8	36	16.7	196	45.7
3	48	22.4	125	58.1	173	40.3
4	0	0.0	30	14.0	30	7.0
5	0	0.0	24	11.2	24	5.6

[Table/Fig-4]: Comparison of Children at two locations according to IQ grades

IQ Grade	No.	IQ Scores			
		Mean	SD	Min	Max
Normal	241	110.1	9.0	79.7	124.1
Very Mild	96	92.6	7.9	70.8	110.8
Mild	44	85.9	9.2	68.6	108.6
Moderate	43	79.0	7.9	66.4	99.7
Severe	5	62.4	2.4	59.7	66.4
Total	429	100.0	15.0	59.7	124.1

[Table/Fig-5]: Association between fluorosis and IQ (Overall)

DI Grade	IQ Grades									
	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5	
	No.	%	No.	%	No.	%	No.	%	No.	%
Normal	6	2.5	184	76.3	50	20.7	1	0.4	0	0.0
Very Mild	0	0.0	10	10.4	79	82.3	6	6.3	1	1.0
Mild	0	0.0	2	4.5	29	65.9	7	15.9	6	13.6
Moderate	0	0.0	0	0.0	15	34.9	16	37.2	12	27.9
Severe	0	0.0	0	0.0	0	0.0	0	0.0	5	100.0

[Table/Fig-6]: Correlation between Fluorosis Grade and IQ Grades (Overall)

this difference was found to be statistically significant (p=0.008). No statistically significant differences (p=0.151) were found between ages of children residing in the two areas.

[Table/Fig-4] shows the comparison of children at two locations according to IQ grades. Majority of children from Tiwariganj (74.8%) had IQ Grade 2 followed by Grade 3 (22.4%) and Grade 1 (2.8%). None of the children from Tiwariganj had IQ Grade lower than 3, while majority of children from Unnao (58.1%) had IQ Grade 3, followed by Grade 2 (16.7%), Grade 4 (14.0%) and Grade 5 (11.2%) and none of the children from Unnao had IQ Grade 1. Difference in IQ grade of children from different habitats was found to be statistically significant (p<0.001).

[Table/Fig-5] shows the association between dental fluorosis and Intelligence Quotient (IQ). Out of 429 children enrolled in the study, 241 individuals whose fluorosis level was graded as normal had

IQ Grade	Female (n=202)		Male (n=227)		Total (n=429)	
	No.	%	No.	%	No.	%
Grade 1	2	1.0	4	1.8	6	1.4
Grade 2	88	43.6	108	47.6	196	45.7
Grade 3	86	42.6	87	38.3	173	40.3
Grade 4	16	7.9	14	6.2	30	7.0
Grade 5	10	5.0	14	6.2	24	5.6

[Table/Fig-7]: Comparison of IQ grades between two genders (Overall)

IQ Grade	6-8 Yrs (n=161)		9-11 Yrs (n=268)		Total (n=429)	
	No.	%	No.	%	No.	%
Grade 1	0	0.0	6	2.2	6	1.4
Grade 2	68	42.2	128	47.8	196	45.7
Grade 3	67	41.6	106	39.6	173	40.3
Grade 4	13	8.1	17	6.3	30	7.0
Grade 5	13	8.1	11	4.1	24	5.6

[Table/Fig-8]: Comparison of IQ grades between two age groups (Overall)

CPM score 29.67±4.05 (Mean IQ 110.1±9.0). IQ score of normal fluorosis index level children was found to be higher than that of children with other grades of fluorosis, and this difference was found to be statistically significant (p<0.001)

[Table/Fig-6] shows the correlation between fluorosis grades and IQ grades. With increase in fluorosis grade, an increase in grade of IQ was observed. Amongst children with IQ grade 1, majority of subjects had normal and very mild fluorosis index (n=190; 78.8%), whereas among subjects with IQ grade 5, all the subjects had severe fluorosis. A strong correlation between fluorosis grade and IQ scores was found (Spearman's p=0.766).

[Table/Fig-7] shows the comparison of IQ grades between two genders. In overall population, difference in IQ Grade of both the genders was not found to be statistically significant (p=0.724).

[Table/Fig-8] shows the comparison of IQ grades between two age groups. In overall population proportional difference in IQ Grade of children from different age groups was found, however this difference was not found to be statistically significant (p=0.105). Since a lot of studies have been conducted in India & worldwide, a comparison of the results of similar studies, in literature, with present study are tabulated [Table/Fig-9].

DISCUSSION

The present study was a cross-sectional study conducted on a stratified random sample of 429 school going children selected from 2 different areas in Lucknow and Unnao with different water fluoride concentrations in their drinking water supply. In the present study, for the estimation of fluoride in drinking water, IS 3025 (Part 60): 2008 (Ion Selective Electrode Method), originally developed by Frant & Ross has been used [16]. This method has been chosen for the reason that it is an automatic analysing system & can be used for estimation of both ionic & non ionic forms of fluoride in contrast to other methods which cannot distinguish between organic and inorganic fluoride [16]. Also, it has tremendous tolerance for extraneous ions like sulfates & phosphates and does calibrations to give final readings in parts per million & is more accurate than the other methods [16].

In this study, on comparison of children at two locations according to IQ grades [Table/Fig-4], majority of the children (74.8%) living in low fluoride area had an IQ grade 2 (definitely above the average in intellectual capacity). None of the children from the low fluoride area had an IQ grade 4 and 5 (definitely below average and intellectually impaired). On the other hand, majority of children (58.1%) from high fluoride area fall under IQ grade 3 (intellectually average). None of the children from high fluoride area had an IQ grade 1 (intellectually

superior). This difference in IQ grades of children amongst the two areas was found to be statistically significant (p<0.001). Sudhir et al., has also reported only 7.8% children with IQ grade 2 and 3 (definitely above the average and intellectually average) in the high fluoride area as compared to 29.9% children with IQ grade 2 and 3 in the low fluoride area [24].

In this study, on analysing the association between different grades of dental fluorosis and IQ grades in the overall study population [Table/Fig-6], it was observed that majority of the fluorosis free children (76.3%) had an IQ grade 2. Only 6 out of 429 children with IQ grade 1 were found in our study, and they were all belonging to the fluorosis free population. No IQ grade 5 children were reported amongst normal population. Majority of the children (82.3%) suffering from very mild dental fluorosis were found to have IQ grade 3. Most of the mild fluorosis index children (65.9%) were also found to have IQ grade 3 followed by IQ grade 4 (15.9%). None of the children with moderate fluorosis were found to have IQ grade 1 and 2. Only five children suffering from severe fluorosis were observed in our study sample and each one of them had an IQ grade 5. Thus it is clearly evident that with increase in the grade of fluorosis, a trend of increase in the IQ grade (decrease in intellectual capacity) was observed indicating a strong correlation between fluorosis grade and IQ grade (Spearman's p=0.766). Sudhir et al., and Shivaprakash et al., in their study have also demonstrated that intellectual capacity of children decreases with increase in the fluorosis grade [4,24].

Possible mechanisms for the neurotoxic effects of fluoride may be explained by several animal studies. Controlled animal studies have shown that rats exposed to drinking water with high concentration of fluoride at weaning were found to have elevated fluoride levels in 6 of 7 brain regions and plasma fluoride levels 7 to 42 times higher than those found in control animals [14]. These were associated with deterioration of learning and memory ability, decreased thickness of post-synaptic density, increased width of synaptic cleft and high cholinesterase activity in brain tissues [30,31].

S.No.	Authors' Name & Year of Study	Place of Study	Sample Size	Results	Results of the present study
1	Karimzade S et al., [21] (2014)	Azerbaijan, Iran	39	The results showed that the mean IQ of children living in high drinking water fluoride region (81.21±16.17) was lower than that of children living in low drinking water fluoride region (104.25±20.73).	The present study showed that the mean IQ scores of fluorosis free children was found to be 110.1+9.0 which is much higher than the mean IQ score of 62.4±2.4 for severe fluorosis children.
2	Nagarajappa R et al., [1] (2013)	Gujrat, India	100	This study concluded that chronic exposure to high levels of fluoride and water is associated with lower IQ.	The present study showed that children living in high fluoride area had lower IQ grades than the children living in low fluoride area.
3	Seraj B et al., [10] (2012)	Makoo, Iran	293	Results showed that the average IQ scores decreased from the normal fluoride group (97.77+18.91) to medium fluoride group (89.03±12,99) to high fluoride group (88.58±16.01)..	Results from the present study showed that the mean IQ scores decreased from fluorosis free children (110.1±9.0) to children having mild fluorosis (85.9±9.2) to children having severe fluorosis (62.4±2.4).
4	Shivaprakash PK et al., [4] (2011)	Karnataka, India	160	Results of this study revealed that children with dental fluorosis had lower IQ (66.63±18.09) than those without dental fluorosis (76.36±20.84).	In the present study, with increase in fluorosis grade, a statistically significant increase in grade of IQ (decrease in intelligence) was observed.
5	Pourlesami HR et al., [22] (2011)	Kerman, Iran	120	Results of this study confirmed that average IQ of high fluoride group (91.37±16.63) was significantly lower than the average IQ of low fluoride group (97.80±15.95).	In the present study, IQ score of normal fluorosis index level children was found to be higher than that of children with other grades of fluorosis, and this difference was found to be statistically significant.
6	Eswar P et al., [23] (2011)	Karnataka, India	133	They arrived at the result that 63.2% of children in high fluoride village had IQ less than 90, versus 47.7% of children in low fluoride village but this difference was not found to be statistically significant.	Statistically significant differences were found between the IQ grades of children living in high & low fluoride areas.
7	Sudhir KM et al., [24] (2009)	Andhra Pradesh, India	1000	Findings of the study suggested that the overall IQ levels in children exposed to high fluoride level were significantly lower than the low fluoride areas.	The present study showed that 100% children with severe fluorosis had IQ Grade 5 whereas all the children with IQ Grade 1 were fluorosis free.
8	Amador DR et al., [25] (2007)	Durango, Mexico	132	The results showed that both fluoride in urine and fluoride in water were significantly correlated with lower IQ in children.	The present study found that fluorosis and IQ levels were affected by drinking water fluoride concentrations as suggested by the significant deficit in IQ of children living in the high fluoride area as compared to those living in low fluoride area.
9	Xiang Q et al., [26] (2003)	Jiangsu, China	512	The mean IQ score of high F village (92.02±13.00) was found to be lower than the mean IQ score of low F village (100.41±13.21). It was therefore concluded that higher drinking water fluoride is significantly associated with higher rates of mental retardation and borderline intelligence, thus lower IQ.	The present study demonstrated that the children living in high fluoride area had lower IQ grades than the children living in low fluoride area.
10	Lu Y et al., [27] (2000)	Tianjin Xiqing, China	118	The mean IQ scores were found to be significantly low in high fluoride area (3.15± 0.61mg/l) than in the low fluoride area (0.37± 0.04mg/l) and hence it was concluded that a real relationship exists between fluoride exposure and intelligence.	The results from the present study confirm that children living in high fluoride area had lower IQ Grades than the children living in low fluoride area.
11	Wang G et al., [28] (1996)	Xinjiang, China	230	Results showed that the average IQ of high F group (95.64±14.34) was lower than in control group (101.23±15.84).	Results from the present study also showed that IQ grades of children with severe fluorosis were higher than those of children with moderate, mild & no fluorosis.
12	Li XS et al., [29] (1995)	Guizhou, China	907	The results demonstrated that the IQ of children living in areas with a medium (79.7±12.7) or severe (80.3±12.9) prevalence of fluorosis was lower than that of children living in areas with slight fluorosis (89.7±12.7) or low fluorosis (89.9±10.4).	Results of the present study showed that majority of the fluorosis free children (76.3%) had Grade 2 IQ scores, majority of children with mild fluorosis (65.9%) had Grade 3 IQ scores, Majority of children with moderate fluorosis (37.2%) had Grade 4 IQ scores whereas all the children with severe fluorosis (100%) had Grade 5 IQ scores.

[Table/Fig-9]: Comparison of results of similar studies conducted in various parts of the world with the present study

Once absorbed in the blood through diet, fluoride forms lipid soluble complexes which cross the blood brain barrier to accumulate in the cerebral tissues [32,33]. The penetrated fluoride complexes adversely affect the CNS development by different neurotoxic mechanisms, such as free radical generation, inhibition of anti-oxidants and mitochondrial energy enzymes and inhibition of glutamate transporters [13]. Studies in aborted human foetuses have shown disruption of neurotransmitters, receptors in nerve cells, increased density of neurons & undifferentiated neuroblasts [34]. There has also been evidence of reduction in number of mitochondria, rough endoplasmic reticulum (RER) and free ribosomes. The structural and functional changes in the CNS, specifically in the foetal period and the first 8 years of life, may lead to learning and intellectual deficits and cognitive dysfunction [14,32,34,35].

On comparison of IQ grades between the two genders [Table/Fig-7], no correlation was found (p=0.724) in the present study. These findings were further supported by the studies conducted by Li et al.,, Zhao et al., Sudhir et al., and Seraj et al., [10,24,29,36]. Nonetheless, in the research of Xiang et al., a significant relationship between IQ and gender was found in one of the two study villages [26]. However, in psychological literatures, gender is mentioned as a non-related factor to IQ [37].

Statistically no significant difference in the IQ of children from different age groups was found [Table/Fig-8]. Thus no correlation between age and IQ was established in the present study that included 6-11-year-old children with 429 subjects. Similar findings were reported by Li et al., and Sudhir et al., [24,29].

A host of many genetic, socio-economical and geographical factors have been known to influence the overall neuro-behavioural development of an individual [19]. Therefore, we have recruited samples from a homogenous rural population of Unnao and Tiwariganj, thus diminishing the effect of some environmental and inherited factors, yet it is obvious that complete exclusion of such factors is impossible.

Certain trace elements in water such as Arsenic and Lead as well as Iodine deficiency, may also affect the intellectual ability of children. Many researchers such as Amador et al., and Wang et al., have shown in their studies that children intelligence can be affected by high levels of Arsenic [25,38]. However, Amador et al., have revealed in their study that in comparison to fluoride, the effect attributable to Arsenic in the IQ reduction is smaller [25]. They have also confirmed through their study that observed deficits in IQ scores cannot be attributed to Lead exposure. Susheela et al., in their study revealed that since fluoride interferes with the activity of thyroid gland and secretion of its hormones, elevated fluoride uptake may cause iodine deficiency in fluorosed individuals, even when they reside in non-iodine deficient areas, hereby affecting the developing brain [39]. Nevertheless, further researches are required to investigate the effect of other environmental or geological contaminants on Intelligence.

LIMTATIONS

In the present study, assessment of the effect of fluoride concentration in drinking water on child's IQ has been done, but it is possible that some other trace elements in drinking water like Arsenic, Lead, Iodine etc. may also have neurological side effects. Thus, further researches are required to investigate the effect of other environmental or geological contaminants on Intelligence.

In the present study, samples from a homogenous rural population of Unnao and Tiwariganj have been recruited to diminish the effect of some environmental and inherited factors, yet it is obvious that complete exclusion of such factors is impossible. Although, children who had a change in the source of drinking water since birth, were excluded in the present study, we could not completely exclude the influence of recall bias. Moreover, fluoride level in a particular source of water may change over a period of time. Therefore, the need for a more careful evaluation of the effect of fluoride on intelligence is emphasized.

CONCLUSION

In the light of all the facts discussed above, the present study that encompasses 429 subjects falling within the age group of 6-11 years, concludes that fluorosis and IQ levels were unaffected by age and gender, however, they were both affected by drinking water fluoride concentrations as suggested by the significant deficit in IQ of children living in the high fluoride area as compared to those living in low fluoride area. The data from this research may support the hypothesis that excess fluoride in drinking water has toxic effects on the nervous system. Millions of children around the world are exposed to high concentrations of fluoride in water and are potentially at risk. Therefore, a close monitoring of fluoride levels in local water supplies from areas with endemic fluorosis and implementing public health measures, such as defluoridation, to reduce the fluoride exposure levels in high fluoride regions seem necessary.

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REFERENCES

[1] Nagarajjappa R, et al. Comparative assessment of Intelligence quotient among children living in high and low fluoride areas of Kutch, India – pilot study. *Iranian Journal of Public Health*. 2013;42(3):813-18.
[2] Fawell J, Baily K, Chilton J, Dahi E, Fewtrell L, Magara Y. Fluoride in drinking water, 1st ed. London: IWA publishing; 2006.
[3] Kauffman JM. Water fluoridation: A review of recent research and actions. *J Am Physicians Surg*. 2005;10:38-44.
[4] Shivaprakash PK, Ohri K, Noorani H. Relation between dental fluorosis and Intelligence quotient in school children of Bagalkot district. *Journal of Indian Society of Pedodontics and Preventive Dentistry*. 2011;29(2):117-20.
[5] Oganessian E, Lencova E, Broukal Z. Is systemic fluoride supplementation for dental caries prevention in children still justifiable? *Pragur Med Rep*. 2007;108:306-14.
[6] Hodge HC. The concentration of fluorides in drinking water to give the point of minimum caries with maximum safety. *JAM Dent Assoc*. 1950;40:436-39.
[7] Dean HT, Arnold FA, Elvove E. Domestic water and dental caries. *Public Health Reports*. 1942;57(32):1155-279.
[8] Shortt HE, Robert GF, Bernard TW, Nayar ASM. Endemic fluorosis in Madras Residency. *Ind J Med Res*. 1937;25(2):553-68.
[9] Raju NJ, Dey S, Das K. Fluoride contamination in groundwater of Sonbhadra District, Uttar Pradesh, India. *Current Science*. 2009;96(7):979-85.
[10] Seraj B, et al. Effect of high water fluoride concentration on the Intellectual development of children in Makoo/Iran. *Journal of Dentistry, Tehran University of Medical Sciences*. 2012;9(3):221-29.
[11] Tewari A, Dubey A, Chaturvedi MK. Assessment of exposure, intake & toxicity of fluoride from groundwater sources. *Rasayan J Chem*. 2012;5(2):199-202.
[12] Varner JA, Karl F, Horvarth JW, Issacson RL. Chronic administration of aluminium fluoride or sodium fluoride to rats in drinking water: alterations in neuronal and cerebrovascular integrity. *Brain Res*. 1998;784:284-98.
[13] Bloylock RL. Excitotoxicity: A possible central mechanism in fluoride neurotoxicity. *Fluoride*. 2004;37:301-14.
[14] Mullenix JP, Denbesten PK, Schunior A, Kernan WJ. Neurotoxicity of Sodium fluoride in rats. *Neurotoxicol Teratol*. 1995;17:169-77.
[15] Srivastava AK, Singh A, Yadav S, Mathur A. Endemic dental and skeletal fluorosis: Effects of high ground water fluoride in some North Indian villages. *International Journal of Oral and Maxillofacial Pathology*. 2011;2(2):7-12.
[16] Frant MS, Ross JW. Electrode for sensing fluoride ion activity in solution. *Science*. 1966;154:1553-55.
[17] Peter Soben. Essentials of preventive and community dentistry. 3rd ed. New Delhi: Arya (Medi) Publishing House; 2006.
[18] Raven J, Raven JC, Court JH. Coloured progressive matrices. 7th ed. Oxford Psychologists Press; 1998
[19] Li Y, Jing X, Chen D, Lin L, Wang Z. Effects of endemic fluoride poisoning on the intellectual development of children in Baotou. *Chinese Journal of Public Health Management*. 2003;19(4):337-38.
[20] Kargul B, Cagler E, Tanboga I. History of water fluoridation. *Journal of Clinical Pediatric Dentistry*. 2003;27(3):213-17.
[21] Karimzade S, Aghaei M, Mahvi AH. Investigation of Intelligence Quotient in 9-12 year old children exposed to high and low drinking water fluoride in West Azerbaijan Province, Iran. *Fluoride*. 2014;47(1):9-14.

[22] Poureslami HR, Horri A, Khoramian S, Garrusi B. Intelligence Quotient of 7-9 year old children from an area with high fluoride in drinking water. *Journal of Dentistry and Oral Hygiene*. 2011;3(4):61-64.
[23] Eswar P, Nagesh L, Devaraj CG. Intelligence Quotients of 10-14 year old school children in a high and a low fluoride village in India. *Fluoride*. 2011;44(3):168-72.
[24] Sudhir KM, Chandu GN, Prashant GM, Subba Reddy VV. Effect of fluoride exposure on Intelligence Quotient (IQ) among 13-15 year old school children of known endemic area of fluorosis, Nalgonda District, Andhra Pradesh. *JIAPHD*. 2009;1(13):88-94.
[25] Amador DR, Navarro ME, Carrizales L, Morales R, Calderon J. Decreased intelligence in children and exposure to fluoride and arsenic in drinking water. *Cademos de Saude Publica*. 2007;23(4):S579-87.
[26] Xiang Q, et al. Effect of fluoride in drinking water on children's intelligence. *Fluoride*. 2003;36(2):84-94.
[27] Lu Y, Sun ZR, Wu LN, Wang X, Lu W, Liu SS. Effect of high fluoride water on intelligence in children. *Fluoride*. 2000;33(2):74-78.
[28] Wang G, Yang D, Jia F, Wang H. A study of the IQ levels of four to seven year old children in high fluoride areas. *Endemic Diseases Bulletin*. 1996;11(1):60-62.
[29] Li XS, Zhi JL, Gao RO. Effect of fluoride exposure on intelligence in Children. *Fluoride*. 1995;28:189-92.
[30] Zhang Z, Xu X, Shen X, Xu XH. Effect of fluoride exposure on synaptic structures of brain areas related to learning memory in mice. *Fluoride*. 2008;41:139-43.
[31] Sun Z, Lui F, Wu L, Lu Y, Yu D. Effects of high fluoride in drinking water on the cerebral function of mice. *Fluoride*. 2008;41:148-51.
[32] Vani ML, Reddy KP. Effects of fluoride accumulation on some enzymes of brain and gastrocnemius muscle of mice. *Fluoride*. 2000;33:17-26.
[33] Niu R, Sun Z, Chang Z, Liu H, Chen H, Wang J. Effects of fluoride and lead on N methyl-D-aspartate receptor I expression in the hippocampus of offspring rat pups. *Fluoride*. 2008;41:101-10.
[34] Yanni, et al. Neurotransmitter and receptor changes in the brain of foetuses from the areas of endemic fluorosis. *Fluoride*. 2008;41:134-38.
[35] Yaming G, Hongmei N, Cuiping F, Hongwei W, Xiaoyan Y. Apoptosis in brain cells of offspring rats exposed to high fluoride and low Iodine. *Fluoride*. 2006;39:173-78.
[36] Zhao LB, Liang GH, Zhang DN, Wu XR, Liang L. Effect of high fluoride water supply on children's intelligence. *Fluoride*. 1996;29:190-92.
[37] Beirne Smith M, Patton JM, Kim SH. Mental Retardation: An introduction to Intellectual Disability. 7th ed. New Jersey: Pearson: 2005.
[38] Wang SX et al. Arsenic and fluoride exposure in drinking water: Children's IQ and growth in Shanyin County, Shanxi Province, China. *Environmental Health Perspectives*. 2007;115(4):643-47.
[39] Susheela AK, Bhatnagar M, Vig K, Mondal NK. Excess fluoride ingestion and thyroid hormone derangements in children living in Delhi, India. *Fluoride*. 2005;38:151-61.

ORAL HEALTH ASSESSMENT FORM (Questionnaire)

Name- Date-
Age- Examiner-
Sex-
Name of School-
Village-
Residence Since-
Any Immigration-
Socioeconomic Status-
Source of Drinking Water-
Duration of Use-
Oral Hygiene Habits –
Never Clean-
Brush-
Dattun-
Any Other-
Frequency –

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