# Original Article

## Effect of Fluoride Concentration in Drinking Water on Intelligence Quotient of 12–14-Year-Old Children in Mathura District: A Cross-Sectional Study

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**Abstract**

**Aims:** The aim was to assess and correlate the influence of the concentration of fluoride in ingested water on the intelligence quotient (IQ) of 12–14-year-old youngsters in Mathura district.

**Materials and Methods:** A total of 219 children were selected, 75 from low F area, 75 medium F area, and 69 from high F area. The concentration of fluoride in the routinely ingested water was estimated using "Ion Selective Electrode method"; then, Raven's Test was utilized to estimate the IQ of the study participants. Independent t-test, Tukey`s post hoc, Chi-square an analysis of variance tests were used to associate the mean and proportion IQ scores in high-, medium-, and low-fluoride regions along with inter-group significant differences ($P \leq 0.05$).

**Results:** The comparison of IQ score showed that 35 (46.7%) participants from the high fluoride and 10 (13.3%) participants from the medium-fluoride areas had below average IQ. Further, it was noted that the lowest mean marks were obtained by the children in the high-fluoride region (13.9467) followed by those in medium (18.9467) and uppermost in least noted fluoride area (38.6087). However, gender-based intergroup comparison did not produce a significant relation with fluoride ($P \geq 0.05$).

**Conclusion:** Concentration of Fluoride in the ingested water was significantly associated with the IQ of children. It has also coined the proportional variability in mental output in accordance to the ingested fluoride level. As two sides of a coin, fluoride cannot be utterly blamed for a lower intelligence in a population; it puts forward a fact that intelligence is a multifactorial variable with a strategic role played by genetics and nutrition to develop cognitive and psychosomatic activities in an individual.

**Keywords:** *Fluorosis, impairment, public health, toxicity*

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### Introduction

This century is accountable to a landmark discovery in preventive dentistry that is fluorides. Since, the day it was first discovered "Fluorides" have always vested in subject of great interest, a topic of lively discussion and matter of much controversy, conflict, and mystery.[1] Fluorides have been extensively used in the battle against dental decay, but this weapon is often discussed as a "Twin Edged Sword" since it's deficit may lead to increased risk of dental caries whereas excess consumption may lead to risk of cumulative intoxication resulting in minor physiological alteration or a major crippling disease.[1]

In India, nearly 74% of population reside in rural backgrounds and lack access to piped or centralized

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water supply. They entirely depend on ground water for drinking purpose which they obtain by drilling bore wells or hand pumps.[2] With population explosion and depletion of water beds, an indiscriminative digging of deep bore wells has led to the usage of water containing high levels of fluoride in different areas.

The majority of the countryside populace utilize ground water for household purposes and lack access to clean potable water and consume the water that is easily accessible to them without knowing the ill effects of such consumption.[3] Excessive concentration of fluoride compounds in the ingested water has owed to major health problems in multiple parts of the country. In India, fluoride-related problems are widespread in about nine states along with nearly 66 million people condemned to risk, of which, 6 million are children.[2,4] Kaj Roholm (1937) noted that "humans may succumb to ill effects of Fluoride far more easily than rodents." In his classical study, he found that cryolite workers who were chronically exposed to fluoride had skeletal fluorosis along with neurological symptoms such as excessive tiredness, excessive fatigue, indisposition, headache, and giddiness.[3,5] Gestatory contact to excessive fluoride levels can have adverse effect on fetal cerebral function and neurotransmitters, as fluoride can penetrate the fetal blood–brain barricade and accumulate in cerebral tissues.[6] This critical phase may hamper neurobehavioral development and affect child's future cognitive and intellectual potentials.[7] A major short coming in this area of research is the small pool of regions in which study has been carried out and most of the resources been collected from the People's Republic of China.[8,9] Researches conducted in different parts of China have indicated an association between higher concentration of fluoride intake and lower intelligence quotient (IQ) in children.[10,11] Similarly, a few studies from India have reported that children residing in regions with endemic fluorosis have lower IQ.[12] With wide spread endemic fluoride areas in India, the prevalent antagonistic effects of high concentration of fluoride in ingested water on IQ level of children can lead to a catastrophic community health concern.[13]

Geographically, the state of Uttar Pradesh rests on a high-fluoride belt with multiple locations showcasing fluorosis as of endemic origin as in Mathura district, Uttar Pradesh, India. Most of the published literature pertaining to the Indian population indicates few isolated incidences without providing a clear picture. Hence, this study was undertaken to answer the dearth of knowledge about fluorides and to assess and correlate the consequence of varied levels of fluoride in ingested water on the IQ of children aged 12–14 years in Mathura district, Uttar Pradesh, India.

## Materials and Methods

### Study design

A cross-sectional study was designed to assess and correlate the impact of fluoride in ingested water on the IQ among children aged 12–14 years in Mathura district, India.

### Study area

Mathura, a district located in the North Indian state of Uttar Pradesh. Mathura district is bordered by Haryana state in the North and by Rajasthan state in the West. It is coordinated in the lat 27°14' to 27°58' North and long 77°17' to 78° 12' East in India covering a total of 3797 km$^2$. The Census of India, 2011, estimates the inhabitants of Mathura to be 441,894 with average population density of 761/km$^2$.[14]

### Sampling

Village samples were selected on the basis of the varied levels of fluoride in the water being consumed in Mathura, India. Study setting consisted of one village with high fluoride (Raya), one medium fluoride (Farah), and one with low-fluoride levels (Charora); of the selected villages, Charora (Group A) consisted of low fluoride (0.60 ppm) village, Farah (Group B) had medium fluoride level (1.70 ppm), and Raya (Group C) had the highest concentration of fluoride in water used for consumption (4.99 ppm). The selected villages had one high school each that had a stable public drinking water supply. From which, convenient sampling strategy was utilized to include all the students aged 12–14 years present on the day of examination who gave consent and satisfied the exclusion and inclusion criteria from the respective schools.

A pilot study that included 10% of the total sample was utilized to check for the feasibility of the study. Then, a study sample of 219 school children aged 12–14 years from the three villages of Farah, Raya, and Charora were brought under study. The individual sample from each village consisted of 75 children from Farah village, 75 from Raya village, and 69 from Charora village, respectively. The villages under study were of similar geographic and demographic characteristics with the inhabitants having similar educational, socioeconomic status, and possessing similar occupation as per the reports of the block development office.

### Inclusion criteria

- Children should be residents of the same village since birth
- Mothers having lived in the same village since their pregnancy
- Inhabitants drinking same ground water.

### Exclusion criteria

- Any birth defects
- Genetic disorders
- History of any head injury
- Systemic diseases
- Children having history of long-term living at places other than the place of birth. All the children who satisfied the inclusion criteria were selected from each age group in all the three villages.

### Ethical clearance and permission

The research protocol was appraised and approved by the Ethical Committee at Mathura, India before the commencement of the study. The ethical approval letter was sanctioned and registered with number "2016/DJD/IEC/A-036." Written permissions were obtained from the "Basic Sikhsha Adhikari" of Mathura and the headmasters of concerned schools. Informed consent was attained from the parents of children, after explaining the study.

A specially prepared format exclusively designed for recording all the required relevant general information was used for recording the data. The time limit set for gathering the data was a period of 3 months from August 2016 to October 2016.

### Training and calibration

Training sessions were carried out for 2 day to standardize and calibrate on the data collection approaches under the aegis of the Department of Pedodontics and Preventive Dentistry, Mathura, with the technical know-how of the Department of Pharmacology, Government Veterinary College in Mathura, Uttar Pradesh, India.

The training sessions composed of revaluation of the outlined criteria, followed by assessment of children based on the replication of field technique to ascertain reliability. The examination was carried out by a team of three examiners and were calibrated, guided, and reference standards were maintained by an expert in the field of preventive dentistry. Dental fluorosis was evaluated using Dean's fluorosis index.[15] Further, Cohen's Kappa was utilized to determine intraexaminer reliability which came to be 0.85.

### Fluoride estimation

Water samples were collected in precleaned polyethylene (nonreactive) bottles from different villages surrounding Mathura district from the hand pumps noted to be the source of consumed water for the inhabitants. The bottles were coded which represented particular village and were then stored in an icebox to preserve the majority of its physical, chemical and biological characteristics. The fluoride concentration in the water sample was then estimated using Fluoride Ion Selective Electrode method (Thermo-Scientific Orion 4 star) at the Department of Pharmacology Veterinary College, Mathura (Uttar Pradesh). Fluoride estimation in the water sample was based on the National Oral Health Survey and Fluoride Mapping 2002–2003.[16]

### Clinical examination

The children were made to sit on the chair, and the oral examination of study subjects was conducted in respective schools using disposable plane mouth mirror under natural light (type 3 examination), and dental fluorosis was ascertained using Modified Dean's fluorosis index (1942).[15] The relevant information related to child's age, sex, and time duration of using the water from that source was recorded. In addition, the history of mother consuming drinking water during her pregnancy was recorded in the format. Data collection and the IQ test administration (Ravens standard progressive matrices [SPM]) were done in the class room of the concerned schools during the study.[17]

### Intelligence quotient estimation

IQ of the participants were measured using SPM Test by John C Raven (1998).[17] Before to administering the test, children were explained and instructed regarding the method of recording their answers. The test was administered to each child in groups of twenty per classroom under the supervision of an investigator to prevent any possible plagiarism. The initial basic scores were corrected into percentile ranks with the help of distribution table, and grades were given according to the instructions in the manual. Scoring was done with the help of key provided in the manual.

### Statistical analysis

The data obtained was compiled systematically and was subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 19 (SPSS Inc., Chicago, IL, USA). The independent *t*-test, one-way analysis of variance, and *post hoc* analysis were utilized to associate the mean marks of children in low-, medium-, and high-fluoride regions and Chi-square test were utilized to compare dental fluorosis scores and IQ scores in all the areas. In addition, the same tests compared the lineage of IQ with gender and age groups.

## Results

Identical numbers of male and female children were included in this study. Appraisal of the IQ levels among the three groups (low-, medium-, and high-fluoride areas) showed a statistically significant difference ($P = 0.05$). None of the children in the low-fluoride region were intellectually compromised when compared to

15 (20%) in the high-fluoride region and 4 (5.3%) in the medium-fluoride areas [Table 1]. In addition, no subject in the low fluoride area had below average IQ in contrast to 35 (46.7%) in the high and 10 (13.3%) in the medium-fluoride areas. Similarly, no one in medium and high fluoride area had either above average or superior IQ when compared to 38 (55.1%) and 9 (13%) children having above average and superior IQ in low-fluoride area, respectively.

On comparing the mean IQ scores among children residing in low, medium, and high fluoride regions a statistically significant difference ($P \leq 0.05$) was noted [Table 2]. It was noted that the lowest mean marks were obtained by children in high-fluoride location (13.9467) followed by those in medium (18.9467) and highest in low-fluoride regions (38.6087). Intergroup comparison produced a statistically significant difference ($P = 0.001$) between the low, medium, and high-fluoride groups [Table 3]. A statistically significant difference was noted in the IQ marks (mean difference = 19.66203) among the children residing in low- and medium-fluoride areas. In addition, a significant difference was noted among the marks (mean difference = 24.66203) obtained by children in low- and high-fluoride regions ($P < 0.001$). Similarly, children residing in medium and high-fluoride regions also had a significant difference ($P < 0.001$) in the marks secured by them (mean difference = 5.00). Intergroup comparison based on Dean's Fluorosis Index showed a statistically significant difference ($P < 0.001$) among all the three groups with different level of fluoride in drinking water [Table 4].

None of the children in the low-fluoride region had dental fluorosis as compared to 8 (10.7%), 45 (60.0%), and 22 (29.3%) children in the high-fluoride area who had mild, moderate, and severe dental fluorosis, respectively.

Comparison of IQ scores to analyze gender-based variability noted that there was no statistical difference ($P = 0.389$) among males and females [Table 5], where 4 (6.9%) females were intellectually impaired as compared to 15 (9.3%) males whereas, only 2 (3.4%) females were of superior level in comparison to 7 (4.3%)

**Table 1: Comparison among the proportion of children based on the levels of intelligence quotient**

| Group | Intellectually impaired (%) | Below average (%) | Average (%) | Above average (%) | Superior (%) | Total (%) | Pearson $\chi^2$ | *P** |
|---|---|---|---|---|---|---|---|---|
| Group A: Low fluoride area (Charora) - 0.60 ppm | 0 | 0 | 22 (31.9) | 38 (55.1) | 9 (13.0) | 69 (100.0) | 184.9 | 0.001* |
| Group B: Medium fluoride area (Farah) - 1.7 ppm | 4 (5.3) | 10 (13.3) | 61 (81.3) | 0 | 0 | 75 (100.0) | | |
| Group C: High fluoride area (Raya) - 2.99 ppm | 15 (20.0) | 35 (46.7) | 25 (33.3) | 0 | 0 | 75 (100.0) | | |
| Total | 19 (8.7) | 45 (20.5) | 108 (49.3) | 38 (17.4) | 9 (4.1) | 219 (100.0) | | |

*Significant ($P \leq 0.05$) test applied: Chi-square test

**Table 2: Comparison of mean intelligence quotient scores in children residing in high-, medium-, and low-fluoride areas**

| Group | *n* | Mean marks±SD | SE | 95% CI for mean | | *P** |
|---|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound | |
| Group A: Charora (low fluoride) | 69 | 38.6087±6.33668 | 0.76285 | 37.0865 | 40.1309 | 0.001 |
| Group B: Farah (medium fluoride) | 75 | 18.9467±4.38330 | 0.50614 | 17.9382 | 19.9552 | |
| Group C: Raya (high fluoride) | 75 | 13.9467±5.13571 | 0.59302 | 12.7650 | 15.1283 | |
| Total | 219 | 23.4292±11.78042 | 0.79605 | 21.8603 | 24.9982 | |

*Significant ($P \leq 0.05$) test applied: ANOVA. SE=Standard error, CI=Confidence interval, SD=Standard deviation, ANOVA=Analysis of variance

**Table 3: *Post hoc* analysis for mutual comparison between all the groups**

| Group | Mean difference | SE | 95% CI | | *P** |
|---|---|---|---|---|---|
| | | | Lower bound | Upper bound | |
| Group A: Charora (low fluoride area) and Group B: Farah (medium fluoride area) | 19.66203* | 0.88676 | 17.5693 | 21.7548 | <0.001 |
| Group A: Charora (low fluoride area) and Group C: Raya (high fluoride area) | 24.66203* | 0.88676 | 22.5693 | 26.7548 | <0.001 |
| Group B: Farah (medium fluoride area) and Group C: Raya (high fluoride area) | 5.00000* | 0.86809 | 2.9513 | 7.0487 | <0.001 |

*Significant ($P \leq 0.05$) test applied: Tukey's *post hoc* analysis. SE=Standard error, CI=Confidence interval

**Table 4: Intergroup comparison based on the levels of dental fluorosis**

| Deans fluorosis index | Groups | | | $\chi^2$ | *P* |
|---|---|---|---|---|---|
| | 0.60 ppm Low fluoride (Group A) (%) | 1.7 ppm Medium fluoride (Group B) (%) | 4.99 ppm High fluoride (Group C) (%) | | |
| Normal | 69 (100.0) | 0 | 0 | 221.9 | <0.001* |
| Questionable and very mild | 0 | 0 | 0 | | |
| Mild | 0 | 14 (18.7) | 8 (10.7) | | |
| Moderate | 0 | 40 (53.3) | 45 (60.0) | | |
| Severe | 0 | 21 (28.0) | 22 (29.3) | | |
| Total | 69 (100.0) | 75 (100.0) | 75 (100.0) | | |

*Significant ($P \leq 0.05$) test applied: Chi-square test

**Table 5: Gender-based comparison of intelligence quotient levels**

| Gender | IQ level | | | | | $\chi^2$ | *P* |
|---|---|---|---|---|---|---|---|
| | Intellectually impaired (%) | Below average (%) | Average (%) | Above average (%) | Superior (%) | | |
| Female | 4 (6.9) | 10 (17.2) | 27 (46.6) | 15 (25.9) | 2 (3.4) | 4.207 | 0.389# |
| Male | 15 (9.3) | 35 (21.7) | 81 (50.3) | 23 (14.3) | 7 (4.3) | | |
| Total | 19 (8.7) | 45 (20.5) | 108 (49.3) | 38 (17.4) | 9 (4.1) | | |

#Nonsignificant ($P \geq 0.05$) test applied: Chi-square test. IQ=Intelligence quotient

**Table 6: Comparison of marks scored between the age groups**

| Age (years) | *n* | Mean marks scored±SD | SE | 95% CI for mean | | Minimum | Maximum | *P* |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound | | | |
| 12 | 90 | 23.7667±12.81506 | 1.35083 | 21.0826 | 26.4507 | 1.00 | 52.00 | 0.799# |
| 13 | 111 | 22.9550±10.98543 | 1.04269 | 20.8886 | 25.0213 | 6.00 | 53.00 | |
| 14 | 18 | 24.6667±11.63160 | 2.74159 | 18.8824 | 30.4509 | 11.00 | 43.00 | |
| Total | 219 | 23.4292±11.78042 | 0.79605 | 21.8603 | 24.9982 | 1.00 | 53.00 | |

#Nonsignificant ($P \geq 0.05$) test applied: One-way ANOVA. SE=Standard error, CI=Confidence interval, SD=Standard deviation, ANOVA=Analysis of variance

males. Although the IQ level was better among the males, but the difference was not statistically significant. Table 6, compares the mean marks secured between the different age groups. The comparison showed that children aged 14 years (23.429 ± 11.78042) scored the highest followed by 12-year-old (23.7667 ± 12.81506) and 13-year-old (22.9550 ± 10.98543), but the variance was found to be statistically non-significant ($P \geq 0.05$).

## Discussion

The present study revealed a positive correlation of IQ with fluoride in ingested water when compared to villages with varied concentration of fluoride (F). In addition, the current study marks one of its kinds of research wherein varied levels of fluoride exposure in the routinely ingested water have been correlated to IQ levels in growing children. The school children from villages with higher standard fluoride level presented with dental fluorosis with a level of severity, i.e. moderate-to-severe.

Outcome measures revealed that exposure to higher levels of F determined by dental fluorosis status of child inferred higher IQ deficit. This designates that early and long-term contact to excess F causes deficits in memory attention, which was contrary to the results of Eswar *et al*.,[18] who concluded that F level in drinking water was not significantly associated with IQ levels of 12–14 year's old school children in a high and low F village of Davangere, Karnataka, India. However, on other side, studies on human fetuses have already shown that developing brain is the ripest targets for disruption by fluoride poisoning. Given that, at early stages of life, i.e. before the age of 6 years, the human brain is in its fastest stage of development, and that around seven and eight basic structural development is completed, therefore, the brain is most vulnerable to damage from excess F intake before this age.[19] The basis of abridged intelligence in children contacted with high levels of F, is the ability of F to pass the blood-brain barrier, bringing about a functional impairment of the nervous system throughout the pre and postnatal development.

In addition, it can permeate through the placenta to the developing fetus and with consequent exposure to fluoride throughout childhood, it may have adversative effects on developing brain thereby causing diminution of intelligence.[20] In this case, the average IQ level of the students exposed to high levels of fluoride in drinking

water was noted to be significantly lower, which was in agreement to the studies conducted by Trivedi *et al*.,[21] Li *et al*.,[22] and Poureslami *et al*.,[23] research also supported that children contacted to fluoride are at the hazard for impaired development of intelligence.

The clear-cut mechanism of action of F in reducing IQ is not well defined; Guan *et al*. demonstrated that F is a chemically ionized element and may effect oxygen metabolism and induce oxygen free radicles which appears to carry a role in diminishing cognitive ability process such as learning and memory.[24] IQ, however, is multifactorial in its development including variances in biological susceptibility, environmental circumstances, and measurement errors. Although there are notable evidences that fluoride exposure has direct link to intelligence, the element that intellectual ability is multifactorial needs to be pondered upon.[25]

Besides the major influence of a high-fluoride environment, education of parents, nutritional status, mother's diet during pregnancy, parental education/care, and endemic lack of iodine also plays a large role in determining IQ development. It is also seen that expectant mothers who diet during pregnancy are placing their babies at risk of low IQ and behavioral problems. The possible effects of these perplexing factors were not taken into consideration. In contrast, the study conducted by Tang *et al*. in China found that child's IQ in association with family income and parent's education level was not in a significant relationship.[26]

The present study paid special attention on the stay of mother during pregnancy, source of drinking water since conception, the socioeconomic status of all the three villages which were same in both endemic and control areas. Researchers have found that cutting back on vital nutrients and calories in the first two trimesters may stunt the development of an unborn child's brain. It supports the opinion that lack of proper diet during pregnancy can hamper the development of fetal organs and the brain, in ways that will have lifetime effects on offspring, potentially reducing IQ, and succumbing to behavioral problems.[27]

In our study, we used SPM test by Raven used to measure IQ of children is a culture fair test which is appropriate to compare people with reverence to their immediate capacities for observation and clear thinking. Although SPM test was designed to encompass the widest conceivable mental ability, a reliable estimate of a person`s capability to reason clearly when allowed to work steadily and uninterrupted at his or her individual speed. Thus, the scores of SPM test represents relative intelligence rather than absolute intelligence. Further, the shortcomings of the IQ test itself, such as emotive stress, apprehension, and unfamiliarity with the testing procedure may greatly affect test performances.[17,28]

The world of fluoride research has progressed rapidly along with extraordinary progress being made in the reduction of scourge of dental caries, much still rests to be carried out. Since the final assessment of effects of any substance on man can be determined only by observation on man himself, all these observations have to be put to test by further experiments. The data from this current study may support the hypothesis that excess F in drinking water has a neurological toxic effect. Therefore, a close observation of the fluoride levels in local water supplies of areas with recorded endemic fluorosis and implementing preventive public health measures to reduce the fluoride exposure levels seem necessary; because intelligence of child is not of concern just to the parents or teachers, but to the individual child itself to carry-on a life of quality and productivity. This will then assist in formulating appropriate defluoridation programs, centralized water supply with optimally monitored F concentration and for spreading awareness that the long-term outcome of higher fluoride concentration can be neutralized.

## Conclusion

The present study lays a milestone to ascertain the devastating effect of F on intelligence of humans. It has also coined the proportional variability in mental output in association to the ingested fluoride. As two sides of a coin, fluoride cannot be utterly blamed for a lower intelligence in a population; it puts forward a fact that intelligence is a multifactorial variable with a pivotal role played by genetics and nutrition to develop cognitive and psychosomatic activities in an individual. Further research would deliver an insight into maternal and paternal genetic influence on child's intelligence and its link with the ingested fluoride.

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## Conflicts of interest

There are no conflicts of interest.

## References

1. Shivaprakash PK, Ohri K, Noorani H. Relation between dental fluorosis and intelligence quotient in school children of Bagalkot district. J Indian Soc Pedod Prev Dent 2011;29:117-20.
2. Brindha K, Elango L. Fluoride in groundwater: Causes, implications and mitigation measures. In: Monroy SD, editor. Fluoride Properties, Applications and Environmental Management. 1st ed. New York: Nova Publishers; 2011. p. 111-36.
3. Mullenix PJ. Fluoride poisoning: A puzzle with hidden pieces. Int J Occup Environ Health 2005;11:404-14.

4. Sharma SK. Toxicity of Fluoride in Parts of Indian Subsurface Water. Available from: http://www.bvsde.paho.org/bvsacd/cd27/sharmask, pdf. [Last accessed on 2017 Mar 03].
5. Kaufman JM. Water fluoridation: A review of recent research and actions. J Am Phys Surg 2005;10:38-44.
6. Shivaraashankara YM, Shivshankara AR. Neurotoxic effects of fluoride in endemic skeletal fluorosis and in experimental chronic fluoride toxicity. J Clin Diag Res 2012;4:740-4.
7. Yugandhar PR, Pratap RK, Praveen K. Neurodegenerative changes in different regions of brain spinal cord and sciatic nerve of rats treated with sodium fluoride. J Med Allied Sci 2011;1:30-5.
8. 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;9:221-9.
9. Zhao LB, Liang GH, Zhang DN, Wu XR. Effect of high fluoride water supply on children's intelligence. Fluoride 1996;29:190-2.
10. Hong F, Cao Y, Yang D, Wang H. Research on the effects of fluoride on child intellectual development under different environment. Fluoride 2001:41:156-60.
11. 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;36:84-94.
12. Jha SK, Nayak AK, Sharma YK. Site specific toxicological risk from fluoride exposure through ingestion of vegetables and cereal crops in Unnao district, Uttar Pradesh, India. Ecotoxicol Environ Saf 2011;74:940-6.
13. Bhatnagar M, Rao P, Saxena A, Bhatnagar R, Meena P, Barbar S, *et al*. Biochemical changes in brain and other tissues of young adult female mice from fluoride in their drinking water. Fluoride 2006;39:280-4.
14. Census Data. Office of the Registrar General and Census Commissioner, India; 2011. Available from: http://www.censusindia.gov.in/2011-Common/CensusData2011.html. [Last accessed on 2017 Mar 03].
15. Dean HT. The investigation of physiological effects by the epidemiological method. In: Fluorine and Dental Health. Vol. 19. Pennsylvania: American Association for the Advancement of Science; 1942. p. 23-32.
16. National Oral Health Survey and Fluoride Mapping 2002-2003. Dental Council of India. Ministry of Health and Family Welfare, Govt. of India. Available from: http://www.dciindia.org.in/Download/Books/NOHSBOOK.pdf. [Last accessed on 2017 Mar 03].
17. Raven JC, Court JH, Raven J. Manual for Raven's Progressive Matrices and Vocabulary Scales: Standard Progressive Matrices. Sec. 3. London: HK Lewis and Company; 1998.
18. Eswar P, Nagesh L, Devraj CG. Intelligence quotients of 12-14 year old school children in a high and low fluoride villages in India. Fluoride 2011;44:168-72.
19. Darchen A, Sivasankar V, Prabhakaran M, Bharathi CB. Health Effects of direct or indirect fluoride ingestion in: Surface modified carbon as scavengers for Fluoride from water. 2016. 1st ed. New Delhi: Springer, p. 33-62.
20. Chen YX, Han F, Zhou Z, Zhang H, Jiao X, Zhang S, *et al*. Research on the intellectual development of children in high fluoride areas. Fluoride 2008;41:120-24.
21. Trivedi MH, Verma RJ, Chinoy NJ, Patel RS, Sathawara NG. Effect of high fluoride water on intelligence of school children in India. Fluoride 2007;40:178-83.
22. Li XS, Zhi JL, Gao RO. Effect of fluoride exposure on intelligence in children. Fluoride 2008;28:189-92.
23. Poureslami HR, Horri A, Garrusi A. A comparative study of IQ of children age 7-9 in a high and a low fluoride water city in Iran. Fluoride 2011;44:163-7.
24. Guan ZZ, Wang YN, Xiao KQ, Dai DY, Chen YH, Liu JL, *et al*. Influence of chronic fluorosis on membrane lipids in rat brain. Neurotoxicol Teratol 1998;20:537-42.
25. Aravind A, Dhanya RS, Narayan A, Sam G, Adarshh VJ, Kiran M. Effect of fluoridated water on intelligence in 10-12-year-old school children. J Int Soc Prev Community Dent 2016;6:237-42.
26. Tang QQ, Du J, Ma HH, Jiang SJ, Zhou XJ. Fluoride and children's intelligence: A meta-analysis. Biol Trace Elem Res 2008;126:115-20.
27. Verma A, Shetty BK, Guddatu V, Chourasia MK, Pundir P. High prevalence of dental fluorosis among adolescents is a growing concern: A school based cross-sectional study from Southern India. Environ Health Prev Med 2017;22:1-7.
28. Sharma P, Singh M, Kumar D, Grover A, Bhardwaj AK. Effect of fluoride exposure through drinking water on the oral health status and intelligence profile of school children of District Una, Himachal Pradesh: An interim analysis. J Evol Med Dent Sci 2016;5:7884-7.