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DOES HIGH FLUORIDE INTAKE CAUSE LOW IQ? A CASE OF ISLAMIC RELIGIOUS SCHOOLS (*MADRASSAS*) IN RURAL AND URBAN AREAS OF SINDH, PAKISTAN

Muhammad Salman Ahmad,[a] Md Nazirul Islam Sarker,[b] M Nauman Ahmad,[c,*]
Madad Ali,[d] Sadiq,[e] Muhammad Abbas[f]

Peshawar, Pakistan

ABSTRACT: This study was carried out to evaluate the intelligence quotient (IQ) in students attending a madrassa, an Islamic religious school, in urban (n=60, boys=38, girls=33) and rural (n=60, boys=48, girls=12) areas, in Sindh province, Pakistan, aged 9–11-years-old, with the same education system and criteria but different socio-economic levels. The fluoride ion (F) concentration in the drinking water was tested in both the rural and urban areas. For the urban madrassas, the mean F level in the drinking water was 2.04 mg/L and the mean urinary F level in the children was 5.99±3.57 mg/L while for the rural madrassas, the F level in the drinking water was 1.07 mg/L and the urinary F level was 3.53±1.09 mg/L. The 38 urban boys had a significantly higher (p<0.05) mean IQ, 99.95±15.50, than the 48 rural boys, 92.30±14.97, despite having a higher drinking water fluoride level, 2.04 mg/L, compared to that of the rural students of 1.07 mg/L. However, several confounding factors were not controlled for including the level of parental education, socio-economic status, and the levels of arsenic, lead, and iodine. No significant differences were found in the distribution of the IQ scores for the total number of students (both boys and girls) between the urban and rural areas, or between the mean IQs for the total boys and total girls, urban and rural girls, urban boys and girls, and rural boys and girls. The detrimental effect of F exposure *in utero* and early childhood reported in other studies may not have been seen in the urban children of the present study, compared to the rural children, because of confounding factors, such as socioeconomic status, sample size, and the ecological rather than individual study design.s

Keywords: Madrassa; Socio-economic conditions; Fluoride; Drinking water; IQ.

INTRODUCTION

The impact of fluoridated water on the intelligence quotient of children is a contentious issue in the science establishment.[1] The fluoride ion (F) is not considered to be essential for the development of healthy teeth and bones[2] and a high F intake can lead to increased child mortality, birth defects, and a lower IQ in children.[3] Numerous studies in China regarding fluoride demonstrate that increased F concentration lowers children's IQ levels.[3] However, other elements, such as social, economic, cultural, demographic, and educational characteristics, also impact children's IQ.[4] There has been growing interest in the impact of fluoride exposure on children's IQ with studies being done in several countries including India, Iran, China, Canada, and Mexico

[a]School of Tourism and Management, Qujing Normal University, Yunnan, 655011, China. E-mail: salman@mail.qjnu.edu.cn; [b]School of Political Science and Public Administration, Neijiang Normal University; [c]Agriculture Chemistry Department, University of Agriculture Peshawar, Pakistan; [d]School of Economics and Management, Qujing Normal University; [e]School of Economics and Management, Neijiang Normal University, Neijiang; [f]Department of Human Nutrition, University of Agriculture, Peshawar, Pakistan. For correspondence: Dr Muhammad Nauman Ahmad, Agriculture Department of Chemistry and Biochemistry, University of Agriculture, Peshawar, Pakistan; E-mail: drnumanahmad@aup.edu.pk.

In Pakistan, no such study has been conducted to find the causes of low IQ in school-going children.[5] This study is carried out in urban and rural areas having high and low F levels but different socio-economic conditions.

Meanings of madrassa: In any Muslim culture, an important segment that extends or broadens religious learning or teaching and preserves norms, way of life, and Islamic values in society is the madrassa, an Islamic religious school. The madrassa is an important institution that gives instruction in Islam, the religion of the Muslims, and a monotheistic faith regarded as being revealed through Muhammad as the Prophet of Allah. The word madrassa originated from the Arabic word "dars," which is a synonym of the term "qara," with both words literally meaning to "read."[6]

A madrassa is a place where Islamic teaching and knowledge is given to a scholar. Usually there is also accommodation and an access to a mosque and library.[7] Madrassas are designated spaces or sacred areas where Islamic teaching and training are given in a customary way, and their educational programmes centre on various Islamic themes. In Pakistan, these Islamic schools may be called "deeni-madaris" where "deeni" has the meaning of "religious." In the Arabic language, "madaris" is the plural of "madrassa."[8] For instance, according to a Pakistani educational report for the year 2015–2016 "deeni-madaris" were described as "educational organizations in which formal religious education is provided." Although the term "madrassa" is at present viewed as a place where only religious schooling is given, in earlier periods madrassas were not seen as providing only religious teachings.[9]

The madrassa system: Traditionally, Pakistan's religious schools or madrassas, were the place where each new generation of Islamic scholars and pastors learn Islamic knowledge. At present, these religious institutions are sponsored by personal donations from Gulf countries and the "Zakat" (donations) system,[10] in which a 2.5% income tax is gathered once a year by the Pakistani government from the information in each Muslim's bank financial record. Each year this system of tax collection brings in a sum of money and this is distributed for use in the religious schools. Overseas assistance comes mainly from countries of the Middle East, from both affluent and generous people and from Islamic charitable trusts.[11]

The exact number of religious schools in Pakistan is unknown.[12] The Pakistan Education Ministry assumes that the number of such religious schools might be 10,000. However, they recognize and infer that number may be higher, with upwards of 1,000,000 to 2,000,000 million scholars going to Islamic learning programs, in any event for a brief period.[13] One of the significant causes behind the fame of the religious schools in Pakistan is the poor state of the country's state-funded educational system and numerous families cannot manage even the small fees that public schools charge. For these low-income families, sending their children to costly private schools is out of the question. In this situation, the religious schools or madrassas offer an alluring option where students are given free education.[14] The growth of madrassa education in Pakistan from 1947–2020 is shown in Table 1.

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Table 1. Growth of madrassa education in Pakistan 1947–2020

Year	No of madrassas	No of teachers	Number of students
Pre-1947	137	–	–
1950	210	–	–
1960	472	1,846	40,239
1971	908	3,185	45,238
1979	1,745	5,005	99,041
1984	1,953	–	–
1986	2,261	12,625	316,380
2001	4,345	–	604,421
2020	12,000	22,124	2,000,000

Source: Madrassa education in Pakistan and Bangladesh[15]

Area profile: Karachi is Pakistan's administrative division in the Sindh province. Karachi is divided into districts. The central district of Karachi is among the most developed and populated areas. The primary language in Karachi central is Urdu spoken by people from India who migrated after the partition in 1947.[16] The position of Karachi central in Karachi, the Sindh province, and Pakistan, is given in Figure 1.

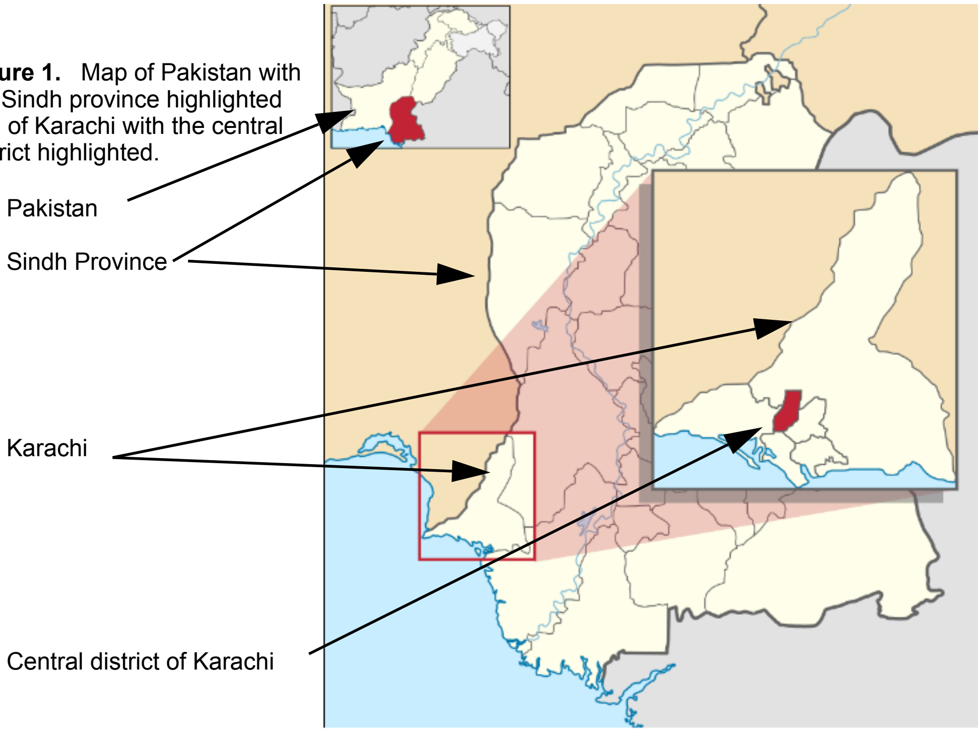

Figure 1. Map of Pakistan with the Sindh province highlighted and of Karachi with the central district highlighted.

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According to the UN study “Multidimensional poverty in Pakistan” for 2014–2115, the prevalence of poverty in Sindh’s urban areas is 10.6%. In the rural areas, which make up most of the province, poverty is alarmingly high at 75.5%. United Nations’ reports indicate that at present 84.7% of the residents in Sindh’s Umerkot district are poor. In 2012–2013, the figure was around 80.7%, while in 2010–2011, it was standing at 75.9%.[17] Umerkot is the oldest but still least developed part of Sindh. The position of Umerkot district in Sindh province and Pakistan, is given in Figure 2.

Figure 2. Map of Pakistan with the Sindh province highlighted and of Sindh province with the Umerkot district highlighted.

Fluoride level in the districts of the Sindh province: The city of Karachi has a huge and growing populace, and a great interest in providing clean consumable water. The deficiency of consumable water has driven individuals of Karachi to utilize subsurface water, which may contain contamination from both alluvial components and from the polluted rivers Lyari and Malir.[18]

These resources have innate contamination with macrobiotic and inorganic substances that are treacherous for well-being. In some places in Sindh province, the underground water is salty and is utilized for other purposes rather than for drinking. For the residents of Karachi, consuming clean water has accordingly become a

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question of incredible concern with a populace of around 20 million, which is almost 10% of the entire population of Pakistan.[19]

Although fluoride has sometimes been regarded as an indispensable ingredient in water and different food intakes for the vigorous growth of human bones and teeth, a current scientifically-based viewpoint is that fluoride is not an essential element for human growth and development and is not necessary for the development of healthy bones and teeth.[20] The fluoride level and content of Karachi drinking water, the river resources, and water in the subsoil of the city have been studied by Saif et al.,[21] Khan et al.,[22] and Siddique et al.[19] The groundwater sampling locations for a number of profiles in a wide range of locales are shown in Figure 3.

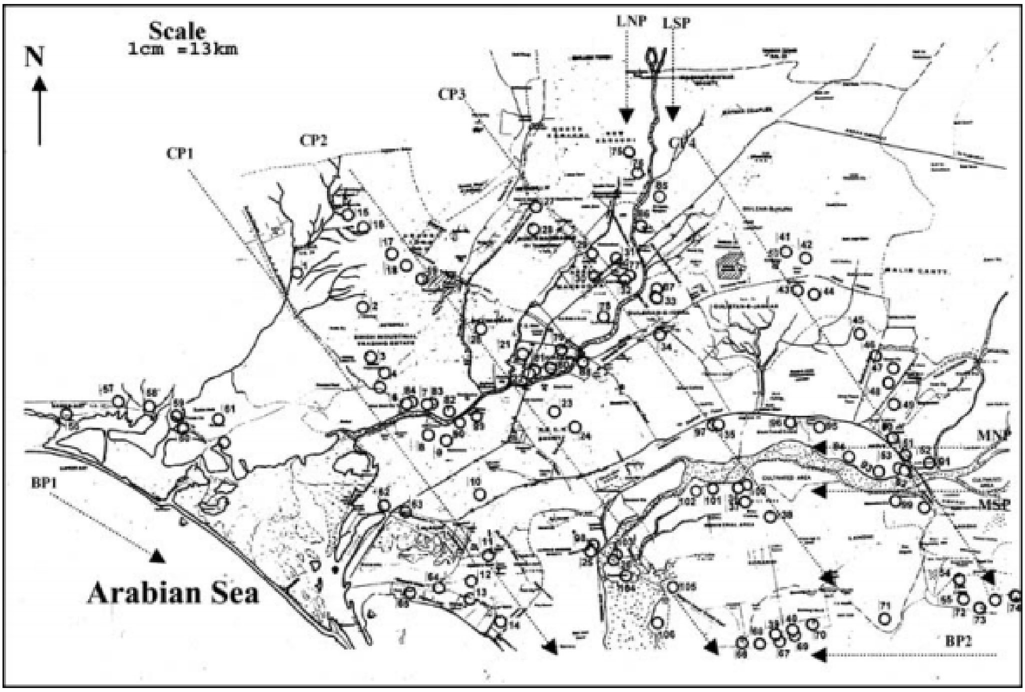

Figure 3. Groundwater sampling locations along each selected profiles. (i) CP1 (1–14), (ii) CP2 (15–26), (iii) CP3 (27–40), (iv) CP4 (41–55), (v) BP1 (56–65), (vi) BP2 (66–74), (vii) LNP (75–84), (viii) LSP (85–90), (ix) MNP (91–98), and (x) MSP (98–106).

The groundwater sites sampled used municipal water via pipelines or subsoil water via tube wells. In Figure 3, pipelines from 1 through 4 (CP1, CP2, CP3, and CP4) lay across the city in a northwest-southeast direction. Similarly, beach profiles 1 and 2 (BP1 and BP2) are another pair of profiles that reflect Karachi's coastal area. Likewise, the profiles along each side of the River Lyari (LNP and LSP), which carry both anthropogenic and hazardous industrial wastewater, were sampled to investigate the effects of industrial effluent on subsoil water.[19]

There is a scarcity of exact information on the fluoride concentration of drinking water in many nations. Pakistan is an example of such a country. Fluoride levels in residential water supplies must be measured to adapt community or individual fluoride prophylactic regimens. In Pakistan, a study was carried out by Khan et al.[23] to measure the fluoride content of several drinking water sources, including in different districts of Sindh as shown in Table 2.

Table 2. Fluoride analysis of drinking water of Sindh by location

Province	Division	District	Population (millions)	Fluoride level (ppm)
Sindh	Hyderabad	Badin	1.1	0.16–0.9
		Dadu	1.63	0.04–0.79
		Hyderabad	2.84	0.04–0.46
		Thatta	1.1	0.04–0.37
	Karachi	Karachi (central)	2.24	0.6–1.46
		Karachi (east)	2.71	0.1–0.15
		Karachi (south)	1.72	0.1–0.14
		Karachi (west)	2.08	0.1–0.15
		Malir	1.04	0.27–0.36
	Larkana	Jacobabad	1.4	0.19–0.57
		Larkana	1.9	0.04–0.74
		Shaikarpur	0.86	0.11–1.17
	Mirpur Khas	Mirpur khas	0.9	0.16–0.58
		Sanghar	1.42	0.1–1.37*
		Tharparkar	0.9	1.05–6.3
		Umer kot	0.66	0.04–0.87
	Sukkar	Ghotki	0.95	0.10–0.49
		Khairpur	1.51	0.13–0.58
		Naushero feroz	1.06	0.04–0.46
		Nawabshah	1.04	0.03–0.18
		Sukkur	0.88	0.27–0.54

MATERIALS AND METHODS

Questionnaire design: In order to find out the F level and the socio-economic status and their relationship with IQ, a thorough research questionnaire was designed and submitted to the Institution's Ethics Review Committee prior to the survey being undertaken.

Ethical approval and sample description: Following ethical approval from the madrassa owners and directors, a pilot research study in high and low fluoride locations was performed. There were more than 230 students registered in madrassa in rural and urban areas and the participants in this cross-sectional study comprised 120 madrassa students, aged 9–11-years-old, in the rural and urban areas of Sindh province, Pakistan. According to the fluoride concentration in the groundwater, the

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participants were determined using a stratified cluster selection of areas based on the geological survey report of the Government of Pakistan.

IQ measurement: The Raven's Progressive Matrices Intelligence Test, with a series of conceptual judgment multiple choice questions in the Urdu and English languages, was employed in the study,. The pamphlet is divided into five sets (A to E), each with 12 elements (e.g., A1 through A12). As the numbers of the sets increase, the items in the pamphlet grow more difficult, requiring a greater cognitive capacity to encode and process the information.

Data collection and statistical analysis: The questions on the pamphlet were explained to the students in the native language to understand the content better, and once they interpreted how to respond, the students were instructed to answer the remaining questions. The Raven's score was determined using the English and Urdu version of the test, delivered by a teacher trained by a psychologist. The answer papers were gathered, collated, and assessed once the Raven's tests were completed at selected areas. SPSS v.13.0 software and GraphPad Prism 6 were used to analyze the data. The t-test and Mann-Whitney test were performed as needed. Means and standard deviations were calculated. Statistical significance was defined as a p value of less than 0.05. The Intelligence Quotient (IQ) was measured with the Chinese Combined Raven's Test. The seven categories distinguished by the IQ test were:

<70	Retarded	(low)
70–79	Borderline	(below average)
80–89	Dull normal	(low average)
90–109	Normal	(average)
110–119	Bright normal	(high average)
120–129	Superior	(good)
>129	Very superior	(excellent)

RESULTS

The level of fluoride in the urine and drinking water of the children in the urban area of Karachi Central and the rural area of Umerkot are shown in Table 3.

Table 3. The level of fluoride (F) in children's urine and water

Area in Sindh province	Nature of area	Number of boys (%)	Number of girls (%)	Urinary F level (mg/L)	F in water (mg/L)
Karachi Central	Urban	38 (44.18)	22 (64.71)	5.99±3.57	2.04
Umerkot	Rural	48 (55.81)	12 (35.29)	3.53 ±1.09	1.07
Total (%)		86 (100)	34 (100)	120 (100)	
Total number of boys and girls (%)		120 (100)			

After completing the tests in both areas, the answer sheets were assessed, and the IQ results related to the drinking water F levels as shown in Table 3 (Table 4).

Table 4. Comparison of the IQ scores between the urban and rural areas with the high and low fluoride levels

IQ category	Water fluoride level		Total number
	High fluoride (urban area) n (%)	Low fluoride (rural area) n (%)	n (%)
IQ <70 retarded (low)	2 (3.33%)	5 (8.33%)	7 (5.83%)
IQ 70–79 borderline (below average)	4 (6.67%)	6 (10%)	10 (8.33%)
IQ 80–89 dull normal (low average)	10 (16.67%)	9 (15%)	19 (15.83%)
IQ 90–109 normal (average)	20 (33.33%)	19 (31.67%)	39 (32.5%)
IQ 110–119 bright normal (high average)	16 (26.67%)	15 (25%)	31 (25.83%)
IQ 120–129 superior (good)	7 (11.67%)	6 (10%)	13 (10.83%)
IQ >129 very superior (excellent)	1 (1.66%)	0 (0.0%)	1 (0.833%)
Total n (%)	60 (100%)	60 (100%)	120 (100)

No significant difference was present between the IQ distribution in the high and low fluoride areas on chi-square testing after combining the groups IQ <70 and IQ 70–79, and the groups IQ 120–129 and IQ >129, so that the cells had an n of 5 or more (p=0.7602, 5 rows and 2 columns, Graphpad Prism 6).

The range of normal average (90–109) occurred for 33.33% (20/60) of the students in the urban madrassas with their high fluoride drinking water levels and in 31.67% (19/60) of the students in the rural madrassas with their low drinking water fluoride levels. Only one student had a superior IQ and attended an urban madrassa with a high fluoride level. No significant differences were found in the distribution of the IQ scores, between the categories of IQ<70 retarded (low) and IQ 70–79 borderline (below average); IQ 80–89 dull normal (low average); IQ 90–109 normal (average); IQ 110–119 bright normal (high average); and IQ 120–129 superior (good) and IQ >129 very superior (excellent), for the total number of students (both boys and girls) between the urban and rural areas (p=0.7602 on chi-square test) (Table 4).

No significant differences were found between the mean IQs for the total boys and total girls (p=0.6354 on unpaired t test with two-tailed p value), urban and rural girls (p=0.2599 on unpaired t test with two-tailed p value), urban boys and girls (p=0.4740 on unpaired t test with two-tailed p value), and rural boys and girls (p=0.6824 on unpaired t test with two-tailed p value) (Table 5).

The mean IQ score of the 38 boys attending the high drinking water fluoride madrassas in urban areas was significantly higher (p=0.0229 on unpaired t test with two-tailed p value) at 99.95±15.50 compared to that of the 48 boys attending the low fluoride madrassas in the rural areas whose mean IQ score was 92.30±14.97 (Table 5).

Table 5. Comparison of children's IQ by gender and drinking water fluoride area in the 86 boys and 34 girls in the total number of students studied of 120.
(values are mean±SD)

Study area	Type of area	Number of boys	Gender IQ (boys)
Karachi (Central)	High fluoride (urban)	38	99.95±15.50
Umerkot	Low fluoride (rural)	48	92.30±14.97*
Total number of boys and mean IQ for boys		86	92.29±15.67
Study area	**Type of area**	**Number of girls**	**Gender IQ (girls)**
Karachi (Central)	High fluoride (urban)	22	96.90±16.31
Umerkot	Low fluoride (rural)	12	90.30±15.49
Total number of girls and mean IQ for girls		34	90.80±14.95

*comparing IQ of high fluoride boys and low fluoride boys p<0.05.

DISCUSSION

The significantly higher IQ, 99.95±15.50, of boys in the urban area madrassas with a high drinking water fluoride level compared to the IQ, 92.30±14.97, of boys in the rural area madrassas with a low drinking water fluoride level contradicts the previous reports of higher fluoride levels being associated with a lower IQ. However, several confounding factors were not controlled for in the present study, including the level of parental education, socio-economic status, and the levels of arsenic, lead, and iodine. The ecologic study by Xiang et al. which found a negative correlation between drinking water fluoride and IQ had a much stronger study design and controlled for family income, parental educational level, lead, arsenic, and iodine.[24-29] Similarly, other studies with a strong study design using individual measurements of fluoride exposure and IQ, and with good consideration of confounding factors, by Bashash et al.,[30] Thomas et al.,[31] Soto-Barreras et al.,[32] Green et al.,[33] and Goodman et al.,[34] also found a negative relationship between fluoride exposure and IQ.

A similar negative relationship was found by Poureslami et al.[35] when they evaluated the IQ level of 120 children, aged 7–9 years, living in high altitude regions in Iran. The mean IQ, 97.80±15.95, of the 60 children living in Baft with a low drinking water fluoride (0.41 mg/L) was significantly higher (p<0.05) than the mean IQ, 91.37±15.63, of 59 children living in Koohbanan with a high drinking water fluoride (2.38 mg/L). Likewise, Chen et al. found that the average IQ, 100.24±14.52,

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of 320 children, aged 7–14 years, in Biji village, China, with a high drinking water fluoride level of 4.55 mg /L, was significantly lower (p<0.01) than the IQ, 104.03±14.96, of 320 children of the same age born and dwelling in Jiaobei in the same county with a low drinking water fluoride level of 0.89 mg /L.[36] Similarly, Guo et al.[37] evaluated the IQs of 60 children aged 7–13-years living in an area with endemic dental fluorosis, affecting 86.46% of the children, and children of the same age range living in non-endemic control area where wood was the main heating fuel with only small amounts of coal being used and where the dental fluorosis rate was<5%. They found the mean IQ of the children in the dental fluorosis endemic area, compared to the control area, was significantly lower and significantly more children had low intelligence, IQ≤69.[37]

Exposure to the fluoride ion can, in sufficient dose, induce neurotoxicity at any age, in both adults and children, but for fluoride-induced neurotoxicity to occur, in response to exposure to low doses of fluoride in the developing brain, the timing of the exposure is of importance.[38] The evidence to date indicates that the developing brain is most sensitive to fluoride-induced neurotoxicity during the intrauterine period.[38] Exposure to a low dose of fluoride later in childhood, at ages approximately 6–13 years, may or may not be associated with a reduction in IQ or school performance.[38] Whether or not fluoride exposure in later childhood is associated with developmental neurotoxicity may reflect the degree to which later childhood exposure parallels intrauterine exposure.[38] In stable societies with a single source of fluoride, such as the water supply, and no fluoride pollution from burning coal or other industrial sources, e.g., the villages of Wamiao and Xinhuai in rural China studied by Xiang et al., a higher correlation may be present between intrauterine and later childhood exposure than in societies where multiple fluoride sources are present such as industrial sources, foods high in fluoride, fluoridated salt, and fluoridated toothpaste, e.g., Mexico City studied by Bashash et al.[30] and Thomas et al.[31] The findings of the studies by Soto-Barreras et al.[32] and Green et al.[33] are also consistent with this interpretation of the data.[38]

Grandjean et al.[39] considered the safe exposure level for fluoride in pregnancy by using data from two prospective studies for benchmark dose modeling. They included mother-child pairs from the Early Life Exposures in Mexico to Environmental Toxicants (ELEMENT) cohort in Mexico[30] and the Maternal-Infant Research on Environmental Chemicals (MIREC) cohort in Canada.[33] Children were assessed for IQ at age 4 (n=211) and between 6 and 12 years (n=287) in the ELEMENT cohort and between ages 3 and 4 years (n=512) in the MIREC cohort. The authors calculated covariate-adjusted regression coefficients and their standard errors to explore the concentration-effect function for maternal urinary fluoride with children's IQ, including possible sex-dependence. Assuming a benchmark response of 1 IQ point, they derived benchmark concentrations (BMCs) of maternal urinary fluoride and benchmark concentration levels (BMCLs). No deviation from linearity was detected from the results of the two studies. Using a linear slope, the BMC for maternal urinary fluoride associated with a 1-point decrease in IQ scores of preschool-aged boys and girls was 0.29 mg/L (BMCL, 0.18 mg/L). The BMC was 0.30 mg/L (BMCL, 0.19 mg/L) when pooling the IQ scores from the older ELEMENT children and the MIREC cohort. Boys showed slightly lower BMC values compared with girls. Relying on the two prospective studies,[30,33] with maternal urine-fluoride exposure at levels commonly occurring in the general population, the joint data showed BMCL results about 0.2 mg/L, corresponding to a protective limit for fluoride in drinking water of less than 0.4 mg/L.[40]

In the present study, following the methods used by Lu et al.[41] and Poureslami et al.,[35] the standardized Raven's IQ test has used to measure IQ. We found the 38 urban boys had a significantly higher ($p<0.05$) mean IQ 99.95±15.50, than the 48 rural boys, 92.30±14.97, despite having a higher drinking water fluoride level, 2.04 mg/L, compared to that of the rural students of 1.07 mg/L. However, several confounding factors were not controlled for including the level of parental education, socio-economic status, and the levels of arsenic, lead, and iodine. No significant differences were found in the distribution of the IQ scores for the total number of students (both boys and girls) between the urban and rural areas, or between the mean IQs for the total boys and total girls, urban and rural girls, urban boys and girls, and rural boys and girls.

Sindh has a population of 47.9 million people, 52.02% of whom live in urban areas and 48.98% reside in rural areas, according to the 2017 census.[42] Karachi is Pakistan's richest urban metropolis, with a multilingual, culturally, and spiritually varied population, and is now one of the country's foremost liberal and economically progressive cities.[43]

Impoverishment is defined as a state in which fundamental human rights are neglected[44] Sindh as a whole, and rural areas in particular, have yearned to break free from poverty for decades, but they continue to suffer from abject poverty.[45] Capron and Duyme found that the children of high socio-economic status parents had significantly higher IQs than the children with low socio-economic status parents.[46] Thus, there is a postpartum environmental effect on IQ performance. Likewise, Ronfani et al.[47] suggested that the home environment, socio-economic status, and intelligence are connected with each other in affecting the different domains of early child development.

Karachi central is the urban area and the most advanced city of Sindh, while Umerkot is the most impoverished region in Sindh, The majority of rural residents are unable to send their children to school.[48] Around 8.7 million children are out of school, working in fields or workshops. Malnutrition is on the rise among prenatal and breastfeeding mothers, as well as in children. Sindh's rural districts have seen the most instability in terms of Human Development Index (HDI) scores, with six of the ten lowest-performing districts being in rural Sindh.[49]

Toulopoulou et al. noted that exposure to an urban environment during early life and low IQ are two well-established risk factors for schizophrenia. They suggested that there was a significant interaction between childhood changes in urbanization in the first ten years and IQ level. In short, those subjects who moved to more or less urban areas before their 10th birthday lost the protective effect of IQ on reducing the risk of developing schizophrenia.[50]

From all that has been reported, it is now clear that an excessive intake of fluoride can produce harmful effects on the developing brain, but socio-economic factors can also play a huge role in a child's cognitive ability. Our study revealed that although

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boys attending madrassas in rural areas had lower drinking water fluoride levels compared to the madrassas in urban areas, the children in the rural areas still performed less well on the IQ test than the children from the urban areas. This is likely to have been an effect of the lower socio-economic status of the parents in the rural areas.

It is suggested that further investigations should be done of the relationship between drinking water fluoride levels and IQ, while keeping in view the various confounding factors that can affect IQ such as socio-economic status, school facilities, teacher education levels, access to basic needs, the levels of iodine, and the exposure to toxins such as lead and arsenic.

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