Introduction
Lead poisoning being among the dominant environmental disease can have life-lasting adverse health effects. Children are more vulnerable to the deleterious effects of this exposure than the adults. However, in countries where leaded gasoline has been banned, there has been a significant decline in average blood lead levels (BLLs). But unsuspecting lead threats, like improper dumping of electronic gadgets and toys defiled with lead, keep emerging. Lead poisoning in kids is a preventable and essential environmental concern and contributes to childhood diseases and maladies. Studies have confirmed biological and neurological impairment associated with behavioural and cognitive damage even at low BLLs. In 2012, the threshold was lowered further to 5μg/dL from 10μg/dL by the United States Centre for Disease Control and Prevention (CDC) and Needleman et al. concluded that significant harm happens even at BLLs <5μg/dL. Lead exposure at an early age can induce a wide variety of problems in children. Among the impacts, the most usual and commonly occurring are subclinical impacts on the behavioural complications, cognitive impairment, central nervous system (CNS) and lower intelligence quotient (IQ) levels. Students with elevated BLLs are more often found to suffer from decreased attention span, lower IQ, absentmindedness and violent behaviour.

Even low levels of lead in children are connected with conduct and learning deficit. While various examinations have featured the impact of early youth lead introduction on intellectual and behavioural deficits, few have associated early childhood lead exposure to school performances universally. One study showed that early youth lead introduction eminently impacted the probability of getting a higher academic degree which is another reason behind achievement and accomplishment gap.

Lead exposure poses a major environmental health threat in Pakistan and various studies have been done in this regard between 1990 and 2010 (Table-1). However, discrete recent studies on a large scale have not yet been performed in recent times. The current study was planned...
to determine BLL of school going children in two cities of Pakistan, and to document the impact of early childhood lead exposure on academic performance.

**Subjects and Methods**
The cross-sectional study was conducted at the Department of Chemical Pathology and Endocrinology, Armed Forces Institute of Pathology (AFIP), Rawalpindi (RWP), Pakistan, from January to December, 2017, and comprised schoolchildren in Rawalpindi, Pakistan, and Hajira, Azad Jammu and Kashmir (AJK). Subjects of either gender were enrolled using non-probability consecutive sampling technique after approval from the institutional review board and written informed consent. Simple randomisation procedure was employed in which if subjects are assigned to groups A and B purely on a random basis. This procedure is the most basic way, and if the total number of subjects is small, then the groups are are likely to be unequal, and, therefore, this method is recommended when the sample is >100. The sample size was calculated using the equation:

\[ \text{Sample size} = \frac{1.96^2 \times (0.5) \times (1 - 0.5)}{0.05^2}, \text{ Sample size } \approx 385 \]

In the equation, \( z = z \) value (e.g. 1.96 for 95\% confidence level), \( p = \) percentage population proportion, expressed as decimal, and \( c = \) error \( (1 - x) = 95\% \), = 0.05 expressed as decimal.

Children suffering from anaemia because of iron deficiency, and those who had zinc supplementation in the preceding six months and those with known instances of thalassaemia characteristics were excluded. Zinc supplementation is considered to lessen lead toxicity.14

Detailed clinical history, including demographic data, sources of lead, symptoms and signs of lead poisoning, and preceding 3 years' academic performance, was recorded on a specially-designed proforma. About 5ml venous blood sample was collected under aseptic measures in potassium-ethylenediaminetetraacetic acid (EDTA) tube for lead level, plasma ferritin and haemoglobin (Hb). Whole blood lead analysis was performed using atomic absorption spectrometry (Agilent Technologies, Malaysia). Lead levels were measured in batches of 50 samples interspersed with calibration checks using ClinChek Controls provided by the manufacturer. Hb analysis was done on Sysmax Haematology analyser (Kobe, Japan). Ferritin was checked using Immulite 2000 (Siemen incorporation, United Kingdom).

Data was analysed using SPSS 24. Data was expressed frequencies and percentages as well as mean ± standard deviation (SD) for qualitative and quantitative variables respectively. Test of associations, like Chi-square, and their significance at \( p<0.05 \) were used to compare BLL school performance, age group, gender and regional distribution. Analysis of variance (ANOVA) tests were used to assess statistical significance of difference of mean BLL for two or more than two groups, like age, region and school performance. It was followed up with Least Significant Difference (LSD) post-hoc test.

**Results**
Of the 400 subjects, 205(51.25\%) were females, and 240(60\%) were from RWP (Table-2). The overall mean age was 9.15±2.8 years. Mean BLL was 4.3±2.6 μg/dL. Mean haemoglobin was 12.9±0.919g/dL and mean ferritin was 49.17±16.0ng/ml. Of the total, 85(21.3\%) showed excellent school performance with mean BLL 3.5±1.7μg/dL, 162(40.5\%) good with mean BLL 3.6±2.2μg/dL, 113(28.3\%) fair with mean BLL 5.50±3.4μg/dL, and 40(10\%) showed poor performance with mean BLL 5.20±2.6μg/dL (Table-3).

Significant negative association was found between school performance and rising mean BLL (\( p<0.05 \)). When further analysed, four of the six comparisons were statistically significant (\( p<0.05 \)) but no major difference was observed in academic performance (Table-4).

There were 324(81\%) children with BLL <5μg/dl, and, among them, mean BLL was the greatest in children with poor school performance 4.18±0.84μg/dl, while the lowest in those with good school performance 2.9±1.3μg/dl. Among the 76(19\%) children with BLL >5μg/dl, the mean BLL was greatest in children with poor school performance 10.0±2.82μg/dL, while the lowest was in those with excellent school performance 6.7±2.3μg/dL. Mean BLL in boys was 4.32±2.9μg/dL compared to 4.30±2.4μg/dL for girls (\( p>0.05 \)). Mean BLL in 221(55.25\%) pre-pubert group was 4.18±2.6 μg/dl compared to 4.47±2.8 μg/dl in 179(44.75\%) subjects in the peri-puberty groups (\( p>0.05 \)). Mean BLL values were significantly different between children of Hajira 3.5±1.2μg/dL and RWP 4.8±3.2μg/dL (\( p<0.05 \)). However, the academic performance of the two region based groups was not significantly different (\( p>0.05 \)). In AJK, 68(42.5\%) children showed good school performance with lowest mean BLL of 3.2±1.18μg/dL, and 19(11.87\%) showed poor school performance with greatest mean BLL of 4.3±0.74μg/dL. In RWP, 46(19.16\%) children showed excellent performance with lowest mean BLL of 3.5±2.1μg/dL and 79(32.91\%) showed fair school performance with greatest mean
Table 1: Results of studies regarding blood lead levels (BLLs) in Pakistan.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study population</th>
<th>Year published</th>
<th>Sample</th>
<th>City</th>
<th>n</th>
<th>Mean (µg/dL)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manser25</td>
<td>Children</td>
<td>1990</td>
<td>School children</td>
<td>Karachi</td>
<td>-</td>
<td>38.2</td>
<td>-</td>
</tr>
<tr>
<td>Sadaruddin26</td>
<td>Adolescents 13-19 years</td>
<td>1995</td>
<td>School children</td>
<td>Islamabad</td>
<td>170</td>
<td>2.38</td>
<td>-</td>
</tr>
<tr>
<td>Hafeez and Malik27</td>
<td>Children &lt;5 years</td>
<td>1996</td>
<td>Population based</td>
<td>Rawalpindi</td>
<td>92</td>
<td>18.8</td>
<td>-</td>
</tr>
<tr>
<td>Malik and Hafeez27</td>
<td>Children 1-5 years, surma users</td>
<td>1999</td>
<td>OPD patients</td>
<td>Rawalpindi</td>
<td>30 (surma users), 29 (pica eating), 33 (none)</td>
<td>21.2 (surma users), 14.55 (none)</td>
<td>-</td>
</tr>
<tr>
<td>Rahman29</td>
<td>Children (30-60 months)</td>
<td>2002</td>
<td>Population based</td>
<td>Karachi (saddar with high traffic)</td>
<td>83</td>
<td>16.46</td>
<td>15.72</td>
</tr>
<tr>
<td>Rahman and Hakeem31</td>
<td>Pregnant women</td>
<td>2003</td>
<td>OPD patients</td>
<td>Karachi (saddar with low traffic)</td>
<td>52</td>
<td>12</td>
<td>4.50</td>
</tr>
<tr>
<td>Khalil32</td>
<td>Children 1-6 years</td>
<td>2004</td>
<td>OPD patients</td>
<td>Lahore</td>
<td>50</td>
<td>9.95</td>
<td>5.77</td>
</tr>
<tr>
<td>Zakir30</td>
<td>Children 7-14 years</td>
<td>2002</td>
<td>School children</td>
<td>Peshawar</td>
<td>60</td>
<td>38.2</td>
<td>-</td>
</tr>
<tr>
<td>Rahman and Hakeem31</td>
<td>Pregnant women</td>
<td>2003</td>
<td>OPD patients</td>
<td>Karachi</td>
<td>73</td>
<td>9.91</td>
<td>4.44</td>
</tr>
<tr>
<td>Khan DA34</td>
<td>Adolescents 13-19 years</td>
<td>2005</td>
<td>Population based</td>
<td>Islamabad</td>
<td>88</td>
<td>3.22</td>
<td>0.20</td>
</tr>
<tr>
<td>Khan DA35</td>
<td>Children 1-6 years</td>
<td>2010</td>
<td>Children of lead-related occupational workers</td>
<td>Wah/ Gujranwala</td>
<td>123</td>
<td>8.1</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2: Region-wise distribution of study population.

<table>
<thead>
<tr>
<th>Subjects Total (n= 400)</th>
<th>Gender</th>
<th>Age Category Pre-puberty (4-9 Years)</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n= 400)</td>
<td>Male (n=195)</td>
<td>Female (n=205)</td>
<td>Pre-puberty (4-9 Years)</td>
</tr>
<tr>
<td>240 (60 %)</td>
<td>129 (66.1%)</td>
<td>111 (54.1%)</td>
<td>130 (58.5%)</td>
</tr>
<tr>
<td>160 (40 %)</td>
<td>66 (33.8%)</td>
<td>94 (45.8%)</td>
<td>91 (41.1%)</td>
</tr>
</tbody>
</table>

Table 3: Comparison of mean blood lead level (BLL) with school performance.

<table>
<thead>
<tr>
<th>Summary</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>85</td>
<td>162</td>
<td>113</td>
<td>40</td>
</tr>
<tr>
<td>Means</td>
<td>3.55</td>
<td>3.66</td>
<td>5.50</td>
<td>5.20</td>
</tr>
<tr>
<td>Standard Deviation (SD)</td>
<td>1.79</td>
<td>2.22</td>
<td>3.44</td>
<td>2.61</td>
</tr>
<tr>
<td>F-value</td>
<td>15.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>0.000*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at 1% level of significance (P<0.05).

BLL 6.3±3.6µg/dL.

Discussion
The current study found a negative impact of high BLLs on academic performance of children in two cities of Pakistan. The relationship between BLLs and school performance suggests that the higher a child’s BLL, the more likely is the chance of poor academic performance. In 2013, a study among elementary and junior high school children in Detroit, Michigan, evaluated the longstanding impact of lead exposure on the performance of children academically in subjects like mathematics, science and reading skills.15 The current study, along with previous...
In Pakistan, lead poisoning still remains a problem as depicted in a recent study conducted in Greece where a large proportion of children with BLLs >5 μg/dL were of Pakistani descent (17.8%), which was much more than anticipated. Another study conducted in New York City showed that 12% of children aged <18 years were of Pakistani descent with BLLs >45 μg/dL. The review article mentioned that in Peshawar, children aged 7-14 years working at automobile workshops as auto mechanics or helpers had mean BLL of 38.2 μg/dL, the mean levels for Islamabad were 22.8 μg/dL, whereas in Karachi, much higher lead levels were recorded ranging between 21.3 and 52.2 μg/dL with a mean of 38.2 μg/dL. A school in Karachi’s posh locality reported none of the children having lead levels <20 μg/dL. Mean BLLs found in the current study is low (4.2 μg/dL) compared to the aforementioned data, but even low BLLs (<5 μg/dL) severely affect academic performance.

Studies in the recent past showed higher BLLs in boys compared to girls, but our results showed no significant difference between genders. The difference can possibly be due to the role of sex hormones etc. Evaluation of how different sources of lead contribute and the exposure influences academic performance is complex, which is likely to differ between areas and population groups. Studies recommend that for every 10 μg/dL of blood lead, IQ is decreased in any event by 1-3 points. At the individual level, this drop may appear to be little and unimportant, but at the population level, little consequences for some people might be a noteworthy burden on society, with decrements in general intellectual performance and economical misfortunes and losses.

A study conducted in 1995 showed a decline in BLL concentrations conducted in schoolchildren of Chak Shehzad, Islamabad. The results reflected very little or no risk to the health of children, indicating that the area is relatively free from lead pollution. A population-based study conducted in Islamabad in 2005 in adolescents aged 13-19 years showed similar results with mean BLL of 3.22 μg/dL.

Our findings are parallel with this descending pattern in BLL, but it ought to be noticed that the Ecuadorian newborn children and youthful kids in 2003-2013 still showed elevated BLLs, with a geometric mean of 15.9 μg/dL, which is as much as three times higher than the present CDC reference estimation of 5 μg/dL. Information gathered in the current study showed that newborn children and youthful kids, who are more prone to clinical and neuro-developmental impacts of lead poisoning, ought to be observed intently by health experts for lead exposure. Values in the study were practically identical to the amount of absorptions found in Karachi (22 μg/dL). The current study showed no significant difference between school performances of the two regions. And there was no difference between mean BLL in pre-puberty (4.18 μg/dL) and peri-puberty categories of children (4.47 μg/dL). In our study, 19% had BLLs >5 μg/dL, indicating a correlation between the BLLs in children and environmental exposure to lead. We hypothesised that the hoisted BLLs in kids residing in Rawalpindi might be simply caused by the exposure of lead. Fresh studies ought to be done to decide the connection between BLLs in children and the genuine lead tainting in the surroundings.

Being first of its kind, the current study consists of findings from RWP, an urban area, and Hajira, a rural area of Pakistan. The results from the rural area can be used as a benchmark for future studies. Indications from rural area results could be from a direct result of improvement on economic background, education level, infrastructure, especially roads, and water supply.

Finally, the results depict the inverse relationship between school performance and BLLs. Children with poor performance had higher BLLs. This relationship additionally proposes that the higher the student's BLL was, the more probable it was that the student would perform poorly. On the basis of the findings, we screened out group of children who showed poor performance which will then be followed up using this criterion in a future study that is being planned.

It must be noted that no studies were found on the association of BLL with school performance in children in Pakistan. Also internationally, majority of studies were related to determination of BLL in children, and a few with blood lead health effects in children. Very few studies with blood lead affecting the IQ level of children.
were found.7,9,16 Also, no specific questionnaire was found assessing a child's association of BLL with school performance.

The current study has its limitations as it only included a few school children in two selected areas of the country. BLL of children in other areas may differ. The study did not measure lead in potential exposure sources, such as soil, dust and air. Lead concentrations were measured only once, rather than serial monitoring throughout the entire time of childhood period. Only subjective evaluation of the children's academic performance by the teachers was used. While the teachers were not aware of the children's BLL, an assessment, such as an IQ test, would have been a better measure of the effects of lead on the children's intellectual capacity, but a validated IQ test was not available in Pakistan during the study period. No physical parameters were measured, while a more thorough medical examination could have revealed other areas of health affected by lead exposure. Since very elaborate and time-consuming scales were used in previous studies for the evaluation of school performance with blood lead in children, such scales could not be used in the current study due to time constraints.

In the light of the findings, we recommend adopting lead administrative techniques to lessen lead outflows from various sources. Usage of institutionalised lead screening programme for kids, particularly those living in lead-defiled zones, ought to be established. Also, lead education targeting public health authorities, paediatricians as well as parents need to be initiated to increase awareness about the problem.

**Conclusion**

Among the subjects, 81% had BLL ≤5μg/dL which is comparable or equivalent to the CDC level of concern. The BLL was inversely related to academic performance. Every single developing country should take all the possible measures to control or dispose of all the possible lead hazards in surroundings of the children before they are exposed to it.

**Disclaimer:** The text is based on an M.Phil. thesis.

**Conflict of Interest:** None.

**Source of Funding:** None.

**References**


