Research Article

Effects of Low-Level Environmental Lead Exposure on the Behavioural Functions of Children in Minia, Egypt

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Abstract
Background: One of the potential negative health outcomes of lead exposure is neurotoxicity and its effect on behaviour. Studies have shown an association between lead exposure and behavioural problems in children. **Objectives:** To study the behavioural disorders associated with environmental low-level Pb exposure in children living in the villages located nearby Minia industrial area. **Subjects:** This study was conducted at three schools in different three villages during the period between October, ١st, ٢٠١٤ to the ٣٠th of June, ٢٠١٥. It included ١٢٠ children aged ٨ years from the nearest ٢ villages to Minia industrial city (٦٠ children each), namely, **North Al-Matahra** and **Nazlt- Hussein,** and ٦٠ children from **Towa**, a village far away from Minia industrial area, as a control group. **Methods:** BLL had been measured, and Conner's test has been done in all studied children. **Results:** BLL of children from **Noth Al- Matahra** and **Nazlt- Hussein** were significantly increased when compared to that of **Towa** children with higher affection reported with **North Al- Matahra**. Conners' test revealed higher affection in children from **North Al- Matahra** and **Nazlt- Hussein** when compared to **Towa.** The most affected behaviours were ADHD, psychsomatic and learning disorders. **Conclusions:** Low level Pb exposure in children of the villages located nearby Minia industrial area was accompanied with behavioral disorders. It is advised to perform a national study to evaluate how big the problem is.
Keywords: Lead toxicity, Behavioural disorders, Metal, Neurotoxicity.

Introduction
Lead poisoning is a type of metal poisoning caused by increase level of heavy metal lead in the body. Classically, lead intoxication has been defined as exposure to high levels of lead typically associated with severe health effects. (Grant, ٢٠٠٩)

Diagnosis and treatment of lead exposure are based on blood lead level (the amount of lead in the blood), measured in micrograms of lead per deciliter of blood (μg/dL). (Trevor et al., ٢٠٠٧),

The US and Centers for Disease Control and Prevention World Health Organization state that a blood lead level of ١٠ μg/dL or above is a cause for concern. However, lead may impair development and have harmful health effects even at lower levels, and there is no known safe exposure level. (Rossi, ٢٠٠٨) and (Barbosa et al., ٢٠٠٥)

Meyer et al., (٢٠٠٣), reported that poor children in developing countries are at especially high risk for lead poisoning. Of North American children, ٧٪ have blood lead levels above ١٠μg/dL, whereas among Central and South American children, the percentage is ٣٣ to ٣٤٪. About one fifth of the world's disease burden from lead poisoning occurs in the Western Pacific, and another fifth is in Southeast Asia.

The nervous system as a control system that interconnects the other body systems. It consists of the brain, spinal cord, and other nerve tissues throughout the body. Behavioural neuroscience is a science that studies the notion of how the nervous system intertwines with other systems in the body to create a specific behavior. It concerns the brain cells, structures, components, and chemical interactions that are involved in order to produce actions (Carlson Neil, ٢٠٠٧).

Dilip, and Joav (٢٠١١), defined by an IQ score below ٧٠ in addition to deficits in two or more adaptive behaviors that affect every day, general living. Once focused almost entirely on cognition, the definition now includes both a component relating to mental functioning and one relating to individuals' functional skills in their environments.

Canfield, et al., (٢٠٠٣), explained that lead is a toxin that has the potential to damage many organ systems in the human body. Although harmful across the lifespan, lead exposure interferes with the development of the central nervous system, and therefore, is particularly dangerous during childhood and early adolescence when critical periods of brain development occur.

Childhood blood lead levels showed small positive associations with externalising problems for boys, and both internalising and externalising problems for girls, at the ١٣-year assessment. Tong et al., (٢٠٠٠)

Subjects and methods

The current study was conducted at three different schools in three different villages related to Minia governorate during the period between October ١st, ٢٠١٤ and ٣٠th of June, ٢٠١٥. It included ١٨٠ children aged ٧- ٩ years old. The study was explained to the mothers of all children and their verbal consents were obtained before performing any step. The questionnaire and samples were taken at schools.

Group I: North Al- Matahra (village I)

It is located nearby the Minia industrial area, ٦٠٠ meters away from it. From the school in this village ١٠٠ children aged ٧- ٩ were selected, and their mothers agreed to participate in the study. After detecting hemoglobin level they become ٧٦ children, and after measuring the BLL they become ٦٠ children.

Group II: Nazlt- Hussein (village II)

It is located nearby Minia industrial area, ٧ km away from it. From the school in this village ١١٤ children aged ٧- ٩ were selected, and their mothers agreed to participate in the study. After detecting hemoglobin level they become ٩٢ children, and after measuring the BLL they become ٦٩ children but ٦٠ children were chosen.

Group III: Towa (village III)

It is located away from the Minia industrial area, ٣٠ km from it, at the west of Minia city; it was considered the control group. From the school in this village ١٥٠ children aged ٧- ٩ were selected, and their mothers agreed to participate in the study. After detecting hemoglobin level they become ٩٦ children, and after measuring the BLL they become ٨١ children but ٦٠ children were chosen.

N.B mothers of all children in all group must be have the same IQ level

Exclusion criteria

This study to be accurate, and to decrease bias the following criteria should be excluded.

- Blood lead level ≥ ١٠µg/dl.
-Mental retardation (MR) or family history of MR.
-Abnormal neurological disorders.
-Systemic or debilitating diseases e.g., malnutrition, anaemia, diabetes mellitus.. etc
-Mentally retarded mothers or tobacco smoking during pregnancy.

Methods

Laboratory investigation:

Blood lead level (BLL)

It mean the blood lead concentration that determined by electrothermal atomic absorption spectrometry using automated drug monitoring system in Lab clinic (Express Plus, Chiron–Diagnostics USA). Lead values were calculated as the means of six analyses of each sample (SD, ٠.٠٣µg/dl [٠.٠٠١µmol/L]). The results of repeated analyses, separated by five days, were highly consistent (SD, ٠.٤٠ µg/dl [٠.٠١٩ µmol/L]) for blood lead concentrations below ٢٠µg/dl (٠.٩٦٦µmol/L). The limit of detection was ١.٠µg/dl (٠.٠٤٨µmol/L), and values below this limit were set to ١.٠µg/dl.

Assessment of behavioural function: This was conducted using Conner's parent Rating Scale-٤٨ (CPRS ٤٨) **Conner's, (١٩٨٩)**

Statistical method:

The collected data were coded, tabulated, and statistically analyzed using SPSS program (Statistical Package for Social Sciences) software version ٢٠. Descriptive statistics were done for numerical data by

mean, standard deviation and minimum& maximum of the range, while they were done for categorical data by number and percentage.

Analyses were done for quantitative data between the three groups using one way ANOVA test followed be post Hoc LSD analysis between each two group. Chi square test was used for qualitative data between groups.

Analyses were done for quantitative data between different sexes using independent sample t- test.

Correlation between two quantitative variables was done by using Pearson's correlation coefficient. Correlation coefficient ranges from (٠-١):- weak (r= -٠.٢٤), fair (r= ٠.٢٥-٠.٤٩), moderate (r= ٠.٥-٠.٧٤), strong (r= ٠.٧٥-١). The level of significance was taken at (P value < ٠.٠٥).

Results

Table (١): Comparison between Blood Lead Level (BLL) and the different parameters of Conner's test in different three groups.

	Group I vs. Group II		Group I vs. Group III		Group II vs. Group III	
	T value	***P*-value**	**T value**	***P*-value**	**T value**	***P*-value**
Lead (µg/dl)	٩.٧٩	< ٠.٠٠١***	١٨.٥٢	< ٠.٠٠١***	٨.٧٢	< ٠.٠٠١***
AD	٢.٧٥	٠.٠٠٧*	٣.٦٦	< ٠.٠٠١***	٠.٩	٠.٣٦٧
ADHD	١.٤١	٠.١٦١	٤.١٢	< ٠.٠٠١***	٢.٧١	٠.٠٠٨**
PSD	٠.٠٢	٠.٩٨٢	٤.٧٤	< ٠.٠٠١***	٤.٧٦	< ٠.٠٠١***
Learning Disorder	١.٤١	٠.١٦١	٣.٥٧	٠.٠٠١***	٢.١٦	٠.٠٣٢**
Conduct Disorder	٢.٤٩	٠.٠١٣*	٦.١٢	< ٠.٠٠١***	٣.٦٢	< ٠.٠٠١***

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder, PSD: Psychosomatic disorders, *: Statistically significant, **: highly significant, ***: very highly significant

Table (٢): Blood Lead Level (BLL) and the different parameters of Conner's test of three groups.

	Group I North Al-Matahra (n=٦٠)	Group II Nazlt-Hussein (n=٦٠)	Group III Towa (n=٦٠)	F	*P* value
Lead (µg/dl) Range Mean ± SD	(٤.٠٩-٩.١٢) ٦.٨٨±٢.٠٢	(٢.٨٦-٦.١١) ٤.٢٤±١.١٩	(١.١١-٤.٠٦) ١.٨٩±١.٠٢	١٧١.٦	<٠.٠٠١***
AD Range Mean ± SD	(٤٨-٧٦) ٥٨.١٢±٦.٥٢	(٤٨-٧٢) ٥٤.٩٨±٦.٠٥	(٤٨-٦٦) ٥٣.٩٥±٦.١٤	٧.٢٧	٠.٠٠١***
ADHD Range Mean ± SD	(٤٨-٧٩) ٥٨.٨٢±٨.٩٩	(٤٨-٧١) ٥٧.٠٥±٦.٧٤	(٤٨-٦٧) ٥٣.٦٥±٣.٩٧	٨.٧٥	<٠.٠٠١***
PSD Range Mean ± SD	(٤٨-٧٧) ٥٩.٩٨±٨.٩٥	(٤٨-٧٣) ٦٠.٠١±٧.٧٤	(٤٨-٧٠) ٥٣.٥٣±٥.١٦	١٥.٠٥	<٠.٠٠١***
Learning Disorder Range Mean ± SD	(٤٨-٧٦) ٥٩.٩٥±٨.٠٨	(٤٨-٧٢) ٥٨.١٢±٧.١١	(٤٨-٧٧) ٥٥.٣١±٦.٠٥	٦.٤٥	٠.٠٠٢**
Conduct Disorder Range Mean ± SD	(٤٨-٧٢) ٥٩.٧١±٦.١٤	(٤٨-٦٦) ٥٦.٩٨±٦.٥٦	(٤٨-٦٥) ٥٣.٠٢±٥.١٨	١٨.٩٣	<٠.٠٠١***

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder, PSD: Psychosomatic disorders, SD: Standard deviation, *: Statistically significant, **: highly significant, ***: very highly significant.

Table (٣): Correlations between Blood Lead Level (BLL) and the outcome of Conner's tests in group I.

Group I **North Al- Matahra** (n=٦٠)	**Blood Lead level**	
	r- value	***P* value**
AD	٠.٥٤١	< ٠.٠٠١***
ADHD	٠.٦٣٩	< ٠.٠٠١***
PSD	٠.٥١٩	< ٠.٠٠١***
Learning disorders	٠.٦٣٥	< ٠.٠٠١***
Conduct disorders	٠.٦٣١	< ٠.٠٠١***

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder, PSD: Psychosomatic disorders, ***: very highly significant.

Table (٤): Correlations between Blood Lead Level (BLL) and the outcome of Conner's tests in group II.

Group II Nazlt- Hussein (n=٦٠)	**Blood Lead level**	
	r- value	***P* value**
AD	٠.٤١٥	٠.٠٠٢**
ADHD	٠.٤٢٣	< ٠.٠٠١***
PSD	٠.٣٩٥	٠.٠٠٣**
Learning disorders	٠.٣١٢	٠.٠٠٩**
Conduct disorders	٠.٤٥٢	< ٠.٠٠١***

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder,
PSD: Psychosomatic disorders, **: highly significant, ***: very highly significant.

Table (٥): Correlations between Blood Lead Level (BLL) and the outcome of Conner's tests in group III

Group III Towa (n=٦٠)	**Blood Lead level**	
	r- value	***P* value**
AD	٠.١١٨	٠.٢٨٩
ADHD	- ٠.١٠٦	٠.٦٧٥
PSD	٠.١٢٣	٠.٨٣٢
Learning disorders	٠.١١٧	٠.١٥٣
Conduct disorders	- ٠.١٩٣	٠.٢٧٩

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder,
PSD: Psychosomatic disorders.

Table (٦): Percentages of the children achieved Conner's test T score ≥ ٦٥ and comparison of the ٣ investigated groups and percentages of males, females.

	Group I North Al-Matahra (n=٦٠)	**Group II Nazlt- Hussein (n=٦٠)**	**Group III Towa (n=٦٠)**	**X^2**	***P* value**
AD					
No	٤٨ (٨٠٪)	٥٦(٩٣.٣٪)	٥٦(٩٣.٣٪)	٧.٢	٠.٠٢٧*
Yes	١٢ (٢٠٪)	٤ (٦.٧٪)	٤ (٦.٧٪)		
ADHD					
No	٤٥ (٧٥٪)	٥٠ (٨٣.٣٪)	٥٧ (٩٥٪)	٩.٢٢	٠.٠١٠**
Yes	١٥ (٢٥٪)	١٠ (١٦.٧٪)	٣ (٥٪)		
PSD					
No	٤٢ (٧٠٪)	٤٧ (٧٨.٣٪)	٥٦ (٩٣.٣٪)	١٠.٧١	٠.٠٠٥**
Yes	١٨ (٣٠٪)	١٣ (٢١.٧٪)	٤ (٦.٧٪)		
Learning Disorder					
No	٤٥ (٧٥٪)	٤٦ (٧٦.٧٪)	٥٥ (٩١.٧٪)	٦.٦	٠.٠٣٧*
Yes	١٥ (٢٥٪)	١٤ (٢٣.٣٪)	٥ (٨.٣٪)		
Conduct Disorder	٥٠(٨٣.٣٪)	٥٥ (٩١.٧٪)	٥٨ (٩٦.٧٪)	٦.٣٧	٠.٠٤٢*
No	١٠ (١٦.٧٪	٥ (٨.٣٪)	٢ (٣.٣٪)		
Yes					
Sex	٣٥(٥٨.٣٪)	٣٣ (٥٥٪)	٣٧ (٦١.٧٪)	٠.٥٤	٠.٧٦٠
Male	٢٥(٤١.٧٪)	٢٧ (٤٥٪)	٢٣ (٣٨.٣٪)		
Female					

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder,
PSD: Psychosomatic disorders, *: Statistically significant, **: highly significant.

Table (٧): Correlations between different parameters of Conner's test in children achieved Conner's test T score ≥ ٦٥ and sex between each two groups.

	Group I vs Group II		**Group I vs Group III**		**Group II vs Group III**	
	X^2	***P*-value**	**X^2**	***P*-value**	**X^2**	***P*-value**
AD	٤.٦٢	٠.٠٣٢*	٤.٦٢	٠.٠٣٢*	٠	١
ADHD	١.٢٦	٠.٢٦١	٩.٤١	٠.٠٠٢**	٤.٢٣	٠.٠٤٠*
PSD	١.٠٩	٠.٢٩٧	١٠.٩١	٠.٠٠١***	٢.٣٤	٠.٠١٩*
Learning Disorder	٠.٠٤٥	٠.٨٣١	٦	٠.٠١٤*	٥.٠٧	٠.٠٢٤*
Conduct Disorder	١.٩١	٠.١٦٨	٥.٩٣	٠.٠١٥*	١.٣٧	٠.٢٤٣
Sex	٠.١٤	٠.٧١٣	٠.١٤	٠.٧٠٩	٠.٥٥	٠.٤٥٩

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder, PSD: Psychosomatic disorders, *: Statistically significant, **: highly significant, ***: very highly significant.

Table (٨): Blood Lead Level (BLL) in children achieved Conner's test (score ≥ ٦٥) in the ٣ investigated groups in relation to different measured parameters.

	Group I North Al-Matahra	**Group II Nazlt- Hussein**	**Group III Towa**	**F**	***P* value**
AD Range Mean ± SD	(٧.٧٥-٩.١٢) ٩.١١±١.٢٤	(٥.٤٦-٦.١١) ٦.٢٤±٠.٧٥	(٢.٩٦-٤.٠٦) ٣.١٢±٠.٩٨	٤٤.٩٨	< ٠.٠٠١***
ADHD Range Mean ± SD	(٦.٠١-٨.٩٤) ٨.٠٣±٢.٠١	(٣.٩٩-٦.٠٣) ٥.١٦±١.٣٥	(٢.٤٥-٤.٠١) ٢.٣٩±٠.٦٢	١٧.٥٤	< ٠.٠٠١***
PSD Range Mean ± SD	(٥.٣٩-٨.٩٢) ٨.١٥±١.٣٦	(٣.٥٩-٥.٩٥) ٥.٢٤±١.٦٣	(٢.٦٥-٣.٨٦) ٢.٥٤±٠.٨٤	٣٢.٣٢	< ٠.٠٠١***
Learning Disorder Range Mean ± SD	(٤.٩٨-٨.٨٢) ٨.١٧±١.٠٣	(٣.٣٩-٥.٩٣) ٥.١٩±١.٨٤	(١.٩٩-٣.٤٢) ٢.٠٤±٠.٧٤	٤٠.١٥	< ٠.٠٠١***
Conduct Disorder Range Mean ± SD	(٦.٤٢-٨.٩٦) ٨.١٢±١.٣٥	(٤.٢٤-٥.٨٢) ٥.٤٦±٠.٩٦	(٢.٦٦-٣.٦٥) ٢.٨٦±٠.١٦	١٩.٩٨	< ٠.٠٠١***

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder,
PSD: Psychosomatic disorders, SD: Standard deviation, ***: very highly significant.

Table (٩): Correlations between Blood Lead Level (BLL) in children achieved Conner's test (score ≥ ٦٥) in each two groups in relation to different measured parameters.

	Group I vs. Group II		**Group I vs. Group III**		**Group II vs. Group III**	
	T value	***P*-value**	**T value**	***P*-value**	**T value**	***P*-value**
AD	٤.٤٢	<٠.٠٠١***	٩.٢٣	<٠.٠٠١***	٣.٩٣	٠.٠٠١***
ADHD	٤.٠٩	<٠.٠٠١***	٥.١٩	< ٠.٠٠١***	٢.٤٥	٠.٠٢٢*
PSD	٥.٥٩	<٠.٠٠١***	٧.١	< ٠.٠٠١***	٣.٣	٠.٠٠٢**
Learning Disorder	٥.٧١	<٠.٠٠١***	٨.٤٦	< ٠.٠٠١***	٤.٣١	< ٠.٠٠١***
Conduct Disorder	٤.٠٥	٠.٠٠١***	٥.٦٧	< ٠.٠٠١***	٢.٥٩	٠.٠٢١*

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder,
PSD: Psychosomatic disorders, *: Statistically significant, **: highly significant,
***: very highly significant.

Table (١٠): Comparison between males and females regarding different parameters of Conner's test using independent sample t test.

	Males (n=١٠٥)	Females (n=٧٥)	T value	*P* value
Lead (µg/dl) Range Mean ± SD	(٢.٨٦-٩.١٢) ٤.٥٦±١.٩٥	(١.١١-٨.٧٩) ٤.٠٣±١.٧٤	١.٨٨	٠.٠٦٢
AD Range Mean ± SD	(٤٨-٧٦) ٥٥.٤٢±٦.٧٢	(٤٨-٧٦) ٥٦.٠٤±٦.٨٦	٠.٦١	٠.٥٤٦
ADHD Range Mean ± SD	(٤٨-٧٧) ٥٦.٢٦±٨.٠٢	(٤٨-٧٩) ٥٦.٨٦±٧.٠٤	٠.٥٢	٠.٦٠٤
PSD Range Mean ± SD	(٤٨-٧٧) ٥٧.٩٨±٧.٨٩	(٤٨-٧٧) ٥٧.٦٤±٧.٤٣	٠.٢٩	٠.٧٧١
Learning Disorder Range Mean ± SD	(٤٨-٧٧) ٥٧.٩٥±٨.٠٢	(٤٨-٧٦) ٥٧.٥٧±٧.٧٩	٠.٣٢	٠.٧٥٢
Conduct Disorder Range Mean ± SD	(٤٨-٧٢) ٥٧.١٢±٧.٠٤	(٤٨-٧٠) ٥٥.٨±٧.١٥	٠.٠٢	٠.٩٨٧

A.D.: Anxiety disorders, ADHD: attention deficit-hyperactivity disorder, PSD: Psychosomatic disorders, SD: Standard deviation.

Discussion

Children were the most susceptible to heavy metal contamination because they absorbed a higher percentage and excreted a lower percentage of metals than adults did. The deleterious effects of the low-level, longterm exposure to heavy metals on children, especially lead, are well known. Behavioral disturbances, impaired mental development, and decrements in cognitive function are typical subclinical sign of intoxication in children that suggested by Banks, et al., (١٩٩٧).

This study included ١٨٠ children aged ٧- ٩ years old, whose mothers accepted the assessment of their children by using Conner's parent Rating Scale and measure blood lead level. Children with Conner's score ≥ ٦٥ points were considered to have a significant behavioral problem.

In ١٩٩١, the CDC, and subsequently the WHO, (١٩٩٥), further reduced the blood lead value defining lead exposure to ١٠µg/dL CDC, (١٩٩١). These ongoing reductions in the acceptable that blood lead concentrations as low as ١٠µg/dL were associated with adverse effects, such as lower intelligence.

On the other hand Dabbas & Al- Zoubi, (٢٠٠٠) and Von Schirnding, et al., (٢٠٠١) reported that in the less developed countries where children are still exposed to Pb from leaded gasoline, traditional cosmetics, lead water pipes, and lead-soldered food cans, the reported BLL in these countries ranged from a concentration as low as a mean of ١٩.٦ µg/L in Jordan to as high as ٥٠–٨٧٪ of children having BLL ≥١٠٠ µg/L in Cape Peninsula, South Africa.

Despite of the mean of BLL in children of North Al- Matahra was (٦.٨٨)µg/L and Nazlt-Hussein (٤.٢٤)µg/L, it associated with ADHD, PSD, learning disorder, anxiety disorder, and conduct disorder, that agree with Guidotti & Ragain, (٢٠٠٧).

In addition BLL in two villages were significantly increased when compared with that of Towa children with higher affection reported in North Al- Matahra as they near the industrial area for long duration like that reported in Nigeria by Adeniyi & Anetor,

(١٩٩٩) and Woolf et al., (٢٠٠٧), who explained that children are more at risk for lead poisoning because their smaller bodies are in a continuous state of growth and development. Lead is absorbed at a faster rate compared to adults, which causes more physical harm than to older people.

Lead exposure in young children in this study has been linked to learning disabilities, and children with blood lead concentrations less than ١٠µg/dL are cause of developmental disabilities, cognitive disorder. Increased blood lead level in children has been correlated with decreases in intelligence, non verbal reasoning, short-term memory, attention deficit hyperactivity disorder, psychosomatic disorder, lower IQ and behavior problems such as aggression, that agree with many authors, Lanphear et al., (٢٠٠٥) and Guidotti & Ragain, (٢٠٠٧), Bellinger, (٢٠٠٨-a), Jusko, et al., (٢٠٠٨), and Kaiser, et al., (٢٠٠١).

Canfield et al., (٢٠٠٤), and Lanphear et al.,(٢٠٠٥), explained that," at lower levels" lead exposure has been associated with a variety of detrimental outcomes including reduced intelligence, and academic impairments, impaired executive functioning and conduct problems, antisocial behavior, and criminality.

On contrary Cleveland et al., (٢٠٠٨) reported that developmental disabilities, cognitive disorder. Occur with blood lead concentration greater than ١٠µg/dL.

In additionn Jakubowski, (٢٠١١), explained that health effects of lead have been focused on children, because they are more vulnerable to lead than adults. Children's behavior and lifestyle (more hand-to mouth activities, being physically closer to ground level, and more time spent outdoors) result in greater intake of lead from contaminated soil or dust compared with adults. Absorption of lead from gastrointestinal tract is higher in children than in adults. There is considerable evidence demon-strating that the developing brain is more vulnerable to the neurotoxicity of lead than the mature brain.

Costa et al., (٢٠٠٤), explained that young children absorb lead at a greater rate than adults, and once absorbed into the body, lead easily crosses the blood–brain barrier. Among the brain regions that are most affected by lead are the prefrontal cortex, hippocampus, basal ganglia, and cerebellum, all of these regions have been implicated in ADHD, including evidence of dysfunction in a cerebellar–prefrontal–striatal network.

Zhang et al., (٢٠٠٢) reported that the nervous system of children is in a stage of rapid development and maturation and is thus particularly susceptible to the toxic effects of lead exposure. Once the blood lead concentration exceeds ٠.٤٨٣µg mol/L in children, learning and memory abilities can be impaired even though noticeable clinical symptoms may not be present.

In this study, Conner's test revealed that there were significant decrements in all measured items in children from villages nearby Minia industrial area, mostly ADHD, PSD, and learning disorder as the numbers of children have score > ٦٥ in ADHD were ١٥ (٢٥٪) in North Al- Matahra, ١٠ (١٦.٧٪) in Nazlt- Hussein but ٣ children only (٥٪) in Towa. As regard PSD, the affected children were ١٨ (٣٠٪) in North Al- Matahra, ١٣ (٢١.٧٪) in Nazlt- Hussein, only ٤ children (٦.٧٪) in Towa. As regard learning disorder children who have score > ٦٥ in North Al-Matahra were ١٥ children (٢٥٪), in Nazlt-Hussein were ١٤ children (٢٣.٣٪), but in Towa only ٥ (٨.٣٪) children affected. So there was significant correlation between three villages that in agreement with Khalaf, et al., (٢٠١٣).

Regarding the relationship between BLL, neurobehavioral function and gender, it has been found that there was no statistically significant variation between males and females regarding the BLL and Conner's test scores in all investigated children which indicates the negative association of sex and lead effects, that in accordance with the results of Lebanese paper done by Nuwayhid et al., (٢٠٠٣), and Khalaf, et al., (٢٠١٣)

This is contradictory to the early reports that considered male gender as a risk factor that reported by International Programme For Chemical Safety (١٩٩٥), CDC (١٩٩١), and

Banks, et al., (١٩٩٧), who reported that boys had significantly more delinquent behaviour problems than girls.

The mechanism(s) by which Pb induces such neuropsychiatric effects explained by Sanders et al., (٢٠٠٩), who suggested that the brain is the organ most sensitive to lead exposure. Lead is able to pass through the endothelial cells at the blood brain barrier because it can substitute for calcium ions and be up taken by Calcium-ATPase pumps. Lead poisoning interferes with the normal development of a child's brain and nervous system; therefore children are at greater risk of lead neurotoxicity than adults are.

Xu et al., (٢٠٠٩), and Zhang et al., (٢٠٠٢) add that lead interferes with the release of glutamate, a neurotransmitter important in many functions including learning, by blocking N-methyl-D-aspartate (NMDA) receptors The targeting of NMDA receptors is thought to be one of the main causes for lead's toxicity to neurons. A Johns Hopkins University report found that in addition to inhibiting the NMDA receptor, lead exposure decreased the level of expression of the gene for the receptor in part of the brain.

Acknowledgement
All thanks to all staff members of department of forensic and toxicology for their support, Dr. Mahmoud Morsi, the lecturer of clinical pathology for his participation in BLL analysis, finally all thanks must be presented to the parents.

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