Journal of Hazardous Materials 186 (2011) 1527–1540

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Effect of some cement components on ion contents in different brain areas of adult male albino mice

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ARTICLE INFO

Article history:
Received 30 June 2010
Received in revised form 2 November 2010
Accepted 7 December 2010
Available online 14 December 2010

Keywords:
Aluminum
Silicon
Iron
Cement
Brain
Ion contents

ABSTRACT

The aim of this study is to investigate the chronic effect of some cement components on the content of ions in different brain areas in adult male albino mice. It is clear that chronic intraperitoneal administration of 0.0013 mg/g aluminum ion caused a significant increase in aluminum, calcium and sodium ions and significant decrease in iron ions, the chronic intraperitoneal administration of 0.00065 mg/g iron caused a significant increase in iron, calcium, and sodium ions but No significant change in potassium and aluminum ions. Chronic intraperitoneal administration of 0.0013 mg/g silicon caused no significant change in calcium, potassium, sodium, aluminum and iron. Chronic intraperitoneal administration of 0.0013 mg/g aluminum, 0.0013 mg/g silicon and 0.00065 mg/g iron, respectively, – using separating time interval 30 min between each – caused a higher elevation in calcium, sodium, aluminum and iron concentrations than the elevation in other groups and no significant change in potassium ions. This may be due to the elevation in glutamate which leads to increase in the intracellular of calcium concentration and the inhibition of membrane-bound Na^+, K^+, Ca^{2+} ATPase activity which lead to cellular alterations and may be death. So long-term exposure to cement components as environmental pollutants may lead to neurodegenerative diseases.

1. Introduction

The cement manufacturing industry is labor intensive. This combined with the large-scale and potentially hazardous nature of the manufacturing process [1]. The route of entry of cement dust in the body is respiratory tract and/or through the gastrointestinal tract by inhalation or swallowing, respectively [2].

Portland cement is a combination of calcium oxide (CaO) (62%–66%), silicon oxide (SiO_2) (19%–22%), Aluminum tri oxide (AL_2O_3) (4%–8%), ferric oxide (Fe_2O_3) (2%–5%), magnesium oxide (MgO) (1%–2%) and also selenium, thallium and other impurities [3].

Iron is a central element of the heme molecule, which is a critical part of hemoglobin and essential for oxygen transport. Having adequate iron ion is important, because as iron ion deficiency sets in, anemia ensues, which, depending on its severity, can lead to fatigability, and decreased exercise tolerance [4]. The previous studies have been suggested that the severity of iron neurotoxic may be proportional to the magnitude of brain iron load [5].

Aluminum is the third most abundant element in the earth's crust representing approximately 8% of total mineral components, exceeded by oxygen (47%) and silicon ion (28%) [6–8]. It is an important element with known toxicity in the human body, mainly in the central nervous system. Although knowledge of Al toxicity has markedly improved in recent years, there is relatively little information regarding its embryotoxicity and teratogenic potential. Its accumulation in kidney promotes degeneration in renal tubular cells, inducing nephrotoxicity. Also, its accumulation in the liver leads to cholestasis [9–11].

Silicon is one of the most abundant elements on the earth. Several investigators have recently shown that silicon ion has a decisive role in growth and bone calcification in higher vertebrates including mammals [12].

The presence of aluminum as aluminum silicates has been confirmed using solid-state 27 Al nuclear magnetic resonance. This finding provides a link with the other major neuropathological picture of Alzheimer disease; the neurofibrilary tangle-bearing neurons, which were high intracellular levels of Al and Si, have also been reported. The focal deposition of this element may be an early and essential factor in the pathogenesis of

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doi:10.1016/j.jhazmat.2010.12.019

Table 1
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g) on the total content of calcium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C.cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	1436.7 ± 103.65	1003.28 ± 93.76	583.8 ± 49.20	1066.1 ± 112.46	1380.86 ± 158.49
	T	1907 ± 135.15	1046.3 ± 64.92	588.35 ± 47.31	1050.4 ± 62.29	1307.2 ± 136.75
	%	32.73%*	4.29%	0.78%	−1.47%	−5.33%
Second week	*C*	1473.37 ± 151.91	1054.15 ± 138.06	640.58 ± 18.38	1106.15 ± 95.92	1682.92 ± 99.03
	T	2144.1 ± 100.03	1108.70 ± 37.35	809.88 ± 67.59	1181.3 ± 56.97	1865.3 ± 147.46
	%	45.53%*	5.17%	26.43%	6.79%	10.84%
Third week	*C*	1504.1 ± 159.71	994.5 ± 95.92	402.31 ± 43.47	1077.48 ± 129.36	1150.41 ± 69.79
	T	2466.1 ± 191.53	1213.4 ± 125.28	848.68 ± 58.2	1264.9 ± 116.05	1924.2 ± 106.54
	%	63.96%*	22.02%	110.95%*	17.39%	67.27%*
Fourth week	*C*	1323.89 ± 101.44	978.03 ± 89.24	532.79 ± 65.96	1046.23 ± 68.7	1223.84 ± 87.3
	T	2651.8 ± 239.03	1297.8 ± 64.01	669.81 ± 36.19	1287.2 ± 72.54	1678.6 ± 108.36
	%	100.3%*	32.7%*	25.716%	23.03%*	37.16%*
Fifth week	*C*	1322.07 ± 124.69	1094.96 ± 130.74	330.15 ± 42.42	986.45 ± 55.62	707.97 ± 36.1
	T	2921.5 ± 134.42	1337.4 ± 66.34	706.13 ± 41.32	1271.9 ± 63.59	925.37 ± 91.99
	%	120.98%*	22.14%	113.88%*	28.94%*	30.71%
Sixth week	*C*	1477.32 ± 44.6	1045.91 ± 104.16	667.4 ± 60.66	940.55 ± 15.94	1889.22 ± 122.69
	T	3112 ± 83	1386.9 ± 115.42	1087.2 ± 84.77	1475 ± 97.75	2082.4 ± 195.97
	%	110.65%*	32.6%*	62.91%*	56.82%*	10.23%
Seventh week	*C*	1723.2 ± 189.57	963.25 ± 99.51	819.02 ± 79.27	1002.18 ± 89.29	1562.57 ± 66.25
	T	2935.1 ± 113.47	1797 ± 91.95	1173.1 ± 165.15	1510.4 ± 74.08	2012.8 ± 195.85
	%	70.33%*	43.24%*	86.56%	50.72%*	28.81%
Eighth week	*C*	1636.86 ± 175.06	933.67 ± 86.38	347.65 ± 17.44	1084.6 ± 52.37	1034.83 ± 98.03
	T	3197.4 ± 15.14	1759 ± 152.83	1157.9 ± 64.53	1749.4 ± 156.02	1404.3 ± 144.64
	%	95.34%*	88.4%*	233.06%*	61.3%*	35.7%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Alzheimer type changes, reflecting an increased exposure to aluminum ion [8].

Many metals that have been suggested to contribute to neurodegenerative diseases are considered to be essential for human health in trace amounts [13]. So the aim of the present study is to investigate the chronic effect of some cement components (aluminum, silicon and iron ions) on the total content of ions (calcium, potassium sodium, iron and aluminum) in different brain areas (cerebellum, brain stem, striatum, hypothalamus and cerebral cortex) of the adult male albino mice.

2. Material and method

The experimental animals used in this study were mice, *Mus musculus* weighing (25–30 g) family Muridae, order Rodentia [14]. Male albino mice of the genus Mus musculus (Swiss strain), aged 3–6 months were provided by the animal house of the National institute of ophthalmology (Giza, Egypt). Animals were maintained under standard laboratory ambient conditions, housed in cages (six mice each) at a constant temperature approximately 22 °C with a 12 h light/dark cycle. Food and water were given ad libitum. The study was carried out in conformity with the animal ethics committee of the National Research Center in Egypt; the animals were divided into five groups. Each group was divided into eight subgroups containing six mice. The first group was serving as control and daily injected intraperitoneal with saline solution (0.9% NaCl). The second group was daily injected with Aluminum ion (0.0013 mg/g) according to Egyptian labor law no. 12 issue 2003 [15], as aluminum chloride $AlCl_3$ [7]. The third group was daily injected with iron ion (0.00065 mg/g) according to Egyptian labor law no. 12 issue 2003 [15], as ferrous chloride $Fe Cl_2$ [16]. The fourth group was daily injected with silicon ion (0.0013 mg/g) according to Egyptian labor law no. 12 issue 2003 [15], as sodium silicate $Na SiO_2$ [17] and the fifth group was daily injected with (0.0013 mg/g aluminum ion, 0.0013 mg/g silicon ion and 0.00065 mg/g iron ion, respectively) according to Egyptian labor law no. 12 issue 2003 [15], utilizing separating time interval 30 min between each ion injection in the fifth group in order to allow silicon ion to reach brain in the peak of aluminum ion distribution in brain tissue which is demonstrated by the presence of measurable Al ion within 30 min [16].

2.1. Dose preparation and administration

Dose provided as threshold limit value for working day in Egyptian labor law is for adult workers, such dose was modified to fit mice according to Paget and Barnes [18], the dose was modified for adult mouse weighing 20 g, according to the variation of mice weights the dose was calculated for each gram body weight.

The duration of injection was up to eight weeks and each subgroup was decapitated weekly during treatment. The brain was carefully removed; dissection was performed on an ice cooled glass plate and five areas were separated according to Glowinski and Iversen [19]. These areas are cerebellum, brain stem, striatum, hypothalamus and cerebral cortex.

The dissected areas were weighed then digested by microwave digestion technique using microwave program supplied by the manufacturer of the microwave. In the presence of HNO_3, samples were analyzed by the atomic absorption spectrometry [20]. Sodium, potassium, calcium and iron ion were measured using flame technique (sodium, potassium and iron ion detected using air-acetylene flame on the other hand calcium detected using nitrous-acetylene flame), while aluminum ion was detected utilizing the graphite furnace technique.

The microwave used to digest the tissue samples was Milestone Ethos TC, Italy, and the atomic absorption used to analyze the samples was Thermo M series at the laboratories of national institute of occupational safety and health.

Value of concentrations of Al, Fe, Na, K and Ca were represented as means ± standard error Statistical analysis was performed using Student's *t*-test [21].

3. Results

As shown in (Table 1), the i.p. injection of 0.0013 mg/g aluminum ion for eight weeks induced significant increase in calcium ion

Table 2
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g) on the total content of potassium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	4956.12 ± 496.48	1174.59 ± 188.93	3162.15 ± 267.03	4062.53 ± 448.42	4099.29 ± 307.14
	T	4913.7 ± 227.81	1012.2 ± 57.07	3100.6 ± 183.04	3966.1 ± 354.07	4071.5 ± 250.86
	%	−0.86%	−13.82%	−1.95%	−2.37%	−0.68%
Second week	*C*	5405.84 ± 348.22	1142.13 ± 31.99	3327.12 ± 297.98	4234.88 ± 270.3	4063.45 ± 213.37
	T	5338.2 ± 378.67	1162.1 ± 107.61	3210.3 ± 89.75	4272 ± 469.92	4105.1 ± 308.2
	%	−1.25%	1.75%	−3.51%	0.88%	1.02%
Third week	*C*	4964.87 ± 247.36	1100.23 ± 72.42	3023.82 ± 54.9	4056.14 ± 247.89	3884.96 ± 416.59
	T	5022.7 ± 467.38	1162.1 ± 88.49	3022 ± 236.11	4049.9 ± 285.04	4029 ± 278.46
	%	1.17%	5.62%	−0.06%	−0.15%	3.71%
Fourth week	*C*	5076.35 ± 307.18	1198.74 ± 91.71	3374.938 ± 71.53	4065.48 ± 315.56	4113.51 ± 165.86
	T	4925.1 ± 422.47	1158.4 ± 94.22	3267.7 ± 145.6	4103.1 ± 224.58	4133.4 ± 138.55
	%	−2.98%	−3.36%	−3.18%	0.93%	0.48%
Fifth week	*C*	4860.11 ± 482.79	1265.94 ± 68.13	3154.99 ± 78.23	4181.31 ± 131.76	4071.93 ± 161.63
	T	4846 ± 182.29	1237.6 ± 127.74	3182.3 ± 171	4062 ± 240.04	4105.8 ± 283.43
	%	−0.29%	−2.24%	0.87%	−2.85%	0.83%
Sixth week	*C*	4906.1 ± 484.59	1137.4 ± 60.03	3145.08 ± 150.72	4483.54 ± 299.66	3785.66 ± 149.81
	T	4807.4 ± 135.89	1132.1 ± 87.66	3145.9 ± 135.78	4156.7 ± 194.54	3797.5 ± 190.02
	%	−2.01%	−0.47%	0.03%	−7.29%	0.31%
Seventh week	*C*	5145.12 ± 278.42	965.94 ± 36.37	3062.73 ± 187.45	4282.24 ± 209.58	4133.23 ± 322.54
	T	5055.5 ± 315.39	944.05 ± 65.52	3058.3 ± 221.79	4158.9 ± 112.7	3967.4 ± 160.06
	%	−1.74%	−2.27%	−0.15%	−2.88%	−4.01%
Eighth week	*C*	4819.67 ± 258.73	1013.11 ± 153.17	3095.08 ± 154.02	4209.9 ± 252.18	3847.06 ± 155.75
	T	4850.4 ± 274.98	1003.5 ± 70.79	3046.5 ± 197.54	4246.8 ± 368.21	3911.2 ± 270.82
	%	0.64%	−0.95%	−1.57%	0.88%	1.67%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals. '*' Significant at ($P < 0.05$).

(Ca^{+2}) content in cerebellum at all the periods of the experiment, in the striatum significant increase was noticed at the fourth, sixth, seventh, and eighth weeks of injection, in the cereberal cortex area significant increase in calcium ion content was noticed at the third, fifth, sixth and eighth weeks of injection, in the hypothalamus area the significant increase in calcium ion content was noticed from the fourth week of injection till the end of the experiment, while in the brain stem area significant increase in calcium was noticed only at the third and fourth weeks of injection. The maximum increase was found in cerebral cortex (+233.06%)) after the eighth week of injection.

The i.p. injection of 0.0013 mg/g aluminum ion for eight weeks induced no change in potassium ion (K^+) content in all tested brain areas of the adult male albino mice all over the experimental periods (Table 2).

Table 3 represents the effect of i.p. injection of 0.0013 mg/g aluminum ion that induced significant increase in sodium (Na^+) content in striatum at the third, fifth, sixth, seventh, and eighth weeks of injection, in the other areas of brain significant increase in the sodium ion content was noticed at the fifth week of injection and persists till the end of the experiment. The maximum increase was found in striatum (133%) after the seventh week.

Table 3
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g) on the total content of sodium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	868.27 ± 68.66	1427.98 ± 129.16	490.51 ± 5.22	804.57 ± 70.23	711.48 ± 26.8
	T	972.9 ± 94.16	1603 ± 60.27	480.84 ± 25.38	818.49 ± 68.05	700.63 ± 36.97
	%	12.05%	12.26%	−1.97%	1.73%	−1.53%
Second week	*C*	941.52 ± 47.57	1790.49 ± 136.41	580.46 ± 43	835.71 ± 71.9	688.89 ± 28.58
	T	972.59 ± 47.64	1733.8 ± 47.79	575.98 ± 33.04	867.19 ± 64.42	775.78 ± 37.8
	%	3.3%	−3.16%	−0.77%	3.77%	12.61%
Third week	*C*	904.41 ± 64.97	1636.83 ± 102.35	470.07 ± 27.35	810.02 ± 82.2	725.07 ± 34.33
	T	1017 ± 39.16	2084.1 ± 120.99	588.78 ± 43.9	945.67 ± 94.5	783.27 ± 7.77
	%	12.45%	27.32%*	25.25%	16.75%	8.03%
Fourth week	*C*	963.86 ± 81.39	1980.99 ± 179.79	506.46 ± 25.42	792.88 ± 66.59	729.43 ± 70.88
	T	1178.2 ± 78.23	2184.4 ± 144.27	634.28 ± 59.95	964.98 ± 34.18	808.43 ± 24.01
	%	22.23%	10.27%	25.24%	21.71%	10.83%
Fifth week	*C*	851.8 ± 54.12	1520.39 ± 112.89	471.86 ± 17.45	712.5 ± 50.64	709.81 ± 32.45
	T	1316.7 ± 38.08	2137.3 ± 129.06	814.01 ± 68.3	1072.7 ± 39.47	878.08 ± 44.52
	%	54.58%*	40.57%*	72.51%*	50.55%*	23.71%*
Sixth week	*C*	924.97 ± 78.61	1440.8 ± 136.95	451.11 ± 28.82	867.5 ± 59.37	699.27 ± 30.27
	T	1332.9 ± 55.65	2674.7 ± 266.17	839.97 ± 31.53	1087.4 ± 56.49	891.47 ± 45.3
	%	44.2%*	85.64%*	86.2%*	25.35%*	27.49%*
Seventh week	*C*	951.85 ± 69.09	1244.7 ± 116.07	468.1 ± 9.7	727.38 ± 64.48	662.28 ± 29.51
	T	1398.9 ± 40.05	2900.2 ± 161.4	850.09 ± 45.39	1122.1 ± 60.54	925.14 ± 21.98
	%	46.97%*	133%*	81.6%*	54.27%*	39.69%*
Eighth week	*C*	804.25 ± 60.75	1409.43 ± 132.82	458.18 ± 24.19	818.43 ± 70.86	647.17 ± 22.42
	T	1670.9 ± 100.12	3060.2 ± 201.78	999.68 ± 77.15	1273.5 ± 77.43	975.26 ± 64.54
	%	107.76%*	117.12%*	118.18%*	55.6%*	50.7%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Table 4
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g) on the total content of iron ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	106.99 ± 9.89	88.99 ± 6.65	45.34 ± 4.41	109.45 ± 8.02	114.45 ± 13.9
	T	96 ± 7.25	91.75 ± 9.62	32.84 ± 3.15	81.03 ± 7.52	82.95 ± 8.35
	%	−10.27%	3.11%	−27.5%*	−25.97%*	−27.53%
Second week	*C*	109.72 ± 10.27	93.73 ± 10.89	55.81 ± 5.45	91.97 ± 8.63	112.07 ± 10.94
	T	85.69 ± 7.65	77.85 ± 5.61	39.68 ± 1.85	79.27 ± 7.24	79.59 ± 7.02
	%	−21.91%	−16.94%	−28.91%*	−13.8%	−31.66%*
Third week	*C*	118.66 ± 12.47	104.45 ± 5.1	55.29 ± 2.93	116.12 ± 11.73	120.68 ± 9.4
	T	72.08 ± 7.55	54.49 ± 5.69	36.04 ± 1.99	79.69 ± 9.42	82.56 ± 5.34
	%	−39.26%*	−47.83%*	−34.82%*	−31.37%*	−31.59%*
Fourth week	*C*	113.05 ± 7.02	84.67 ± 5.77	52.11 ± 4.49	94.45 ± 8.45	111.31 ± 8.91
	T	75.14 ± 8.73	54.92 ± 6.92	39.71 ± 2.53	63.13 ± 6.39	51.56 ± 2.68
	%	−33.54%*	−35.13%*	−23.79%*	−33.16%*	−53.68%*
Fifth week	*C*	91.16 ± 8.16	82.79 ± 8.61	42.54 ± 1.27	93.98 ± 5.16	109.75 ± 6.2
	T	70.41 ± 2.17	41.83 ± 4.61	38.6 ± 0.84	60.64 ± 3.15	55.2 ± 5.94
	%	−22.76%*	−49.47%*	−9.26%*	−35.48%*	−49.7%*
Sixth week	*C*	100.42 ± 10.81	85.15 ± 7.88	51.37 ± 5.35	100.5 ± 11.24	114.93 ± 9.15
	T	70.17 ± 4.87	34.51 ± 2.67	33.97 ± 1.49	59.83 ± 7.11	48.32 ± 1.91
	%	−30.12%*	−59.47%*	−33.88%*	−40.46%*	−57.96%*
Seventh week	*C*	100.41 ± 6.49	93.53 ± 10.36	43.36 ± 4.23	90.99 ± 3.99	105.35 ± 7.72
	T	61.46 ± 2.94	40.64 ± 4.28	30.15 ± 1.44	56.53 ± 5.21	45.9 ± 4.22
	%	−38.8%*	−56.54%*	−30.48%*	−37.87%*	−56.43%*
Eighth week	*C*	118.04 ± 11.06	98.37 ± 10.11	40.78 ± 3.77	116.98 ± 8.44	103.9 ± 7.96
	T	59 ± 6.61	36.79 ± 3.75	28.82 ± 1.96	44.2 ± 3.18	44.62 ± 2.72
	%	−50%*	−62.6%*	−32.64%*	−62.21%*	−57.05%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

As illustrated in (Table 4), the i.p. injection of 0.0013 mg/g aluminum ion induced significant decrease in the total content of iron ion in cerebellum and striatum from the third week of injection till the end of the experiment, in the hypothalamus the significant depression in the iron ion concentration was noticed through all the periods of the experiment except in the second week, while in the midbrain area the decrement in iron ion content was noticed from the second week and persists till the end of the experiment, finally in the cerebral cortex all the weeks of the experiment show significant decrease in the concentration of the iron ion content. The maximum decrease was found in hypothalamus (−62.21%) after the eighth week.

As shown in (Table 5), the i.p. injection of 0.0013 mg/g aluminum ion for eight weeks induced significant increase in aluminum ion (Al) content from the second week till the eighth week in all tested brain areas except the brain stem shows significant increase in aluminum by the third week, while no significant change was noticed at the first week of the experiment in all tested brain areas. The maximum increase was found in cerebral cortex (+64.41%) after the eighth week.

Table 5
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g) on the total content of aluminum ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem(μg/g ± S.E.)
First week	*C*	91.78 ± 8.4	119.53 ± 7.9	28.77 ± 1.5	79.73 ± 6.25	52.63 ± 2.27
	T	97.25 ± 3.12	136 ± 5.85	30.02 ± 4.37	81.43 ± 5.57	56.27 ± 5.62
	%	5.97%	13.78%	4.37%	2.13%	6.91%
Second week	*C*	83.66 ± 2.12	126.68 ± 6.75	24.12 ± 1.12	62.78 ± 4.36	53.91 ± 3.49
	T	115.96 ± 4.23	170.15 ± 8.63	31.53 ± 0.96	88.43 ± 7.87	63.35 ± 3.56
	%	38.61%*	34.31%*	30.76%*	40.86%*	17.82%
Third week	*C*	73.78 ± 6.32	117 ± 10.95	23.1 ± 2.04	71.14 ± 4.28	51.33 ± 4.69
	T	103.6 ± 6.1	178.566 ± 17.616	32.51 ± 2.07	97.11 ± 9.76	66.96 ± 3.47
	%	40.42%*	52.45%*	40.69%*	36.5%*	30.45%*
Fourth week	*C*	80.1 ± 6.74	113.11 ± 11.92	24.29 ± 1.41	62.55 ± 2.29	49.27 ± 3.21
	T	107.91 ± 8.78	165.38 ± 9.53	35.29 ± 1.98	94.79 ± 4.32	68.8 ± 5.3
	%	34.72%*	46.21%*	45.24%*	51.54%*	39.64%*
Fifth week	*C*	80.18 ± 5.16	113.09 ± 7.74	24.79 ± 2.73	71.62 ± 7.14	45.21 ± 3.82
	T	117.75 ± 9.85	159.97 ± 13.79	39.18 ± 3.19	100.23 ± 4.41	69.78 ± 4.31
	%	46.87%*	41.46%*	58.03%*	39.94%*	54.35%*
Sixth week	*C*	85.16 ± 4.55	114.41 ± 8.09	26.82 ± 1.41	74.95 ± 3.63	51.14 ± 5.29
	T	122.49 ± 4.5	146.23 ± 12.68	40.72 ± 1.22	103.83 ± 5.83	72.68 ± 2.67
	%	43.83%*	27.81%	51.82%*	38.45%*	42.11%*
Seventh week	*C*	82.43 ± 7.78	112 ± 2.85	26.92 ± 2.1	68.83 ± 4.62	52.53 ± 5.21
	T	120.93 ± 8.53	170.83 ± 9.48	38.17 ± 1.75	106.17 ± 3.35	78.25 ± 6.65
	%	46.71%*	52.52%*	41.79%*	54.26%*	48.95%*
Eighth week	*C*	86.14 ± 5.36	118.76 ± 10.62	24.93 ± 2.08	77.28 ± 5.56	54.61 ± 4.88
	T	134.81 ± 10.37	152.16 ± 9.21	40.98 ± 1.38	109.73 ± 11.92	71.97 ± 2.06
	%	56.49%*	28.12%*	64.41%*	41.99%*	31.79%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Table 6
Effect of chronic i.p. injection of iron ion (0.00065 mg/g) on total content of calcium ion in different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C.cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	1436.7 ± 103.65	1003.28 ± 93.76	583.8 ± 49.20	1066.1 ± 112.46	1380.86 ± 158.49
	T	1489.7 ± 131.13	1053.7 ± 72.22	637.43 ± 31.56	1173.5 ± 36.52	1449.2 ± 59.29
	%	3.693%	5.031%	9.187%	10.080%	4.953%
Second week	*C*	1473.37 ± 151.91	1054.15 ± 138.06	640.58 ± 18.38	1106.15 ± 95.92	1682.92 ± 99.03
	T	1631.4 ± 103.39	1128 ± 96.87	638.5 ± 20.53	1122.5 ± 79.69	1715.7 ± 74.83
	%	10.726%	7.001%	−0.325%	1.482%	1.945%
Third week	*C*	1504.1 ± 159.71	994.5 ± 95.92	402.31 ± 43.47	1077.48 ± 129.36	1150.41 ± 69.79
	T	1720 ± 57.3	1256.6 ± 100.49	685.76 ± 26.91	1172.8 ± 42.13	1831.8 ± 82.91
	%	14.355%	26.352%	70.454%*	8.850%	59.23%*
Fourth week	*C*	1323.89 ± 101.44	978.03 ± 89.24	532.79 ± 65.96	1046.23 ± 68.7	1223.84 ± 87.3
	T	1756.7 ± 53.95	1280 ± 72.7	706.29 ± 16.11	1232.2 ± 82.94	2078 ± 53.32
	%	32.692%*	30.874%*	32.564%*	17.771%	69.792%*
Fifth week	*C*	1322.07 ± 124.69	1094.96 ± 130.74	330.15 ± 42.42	986.45 ± 55.62	707.97 ± 36.1
	T	2112.7 ± 78.53	1361.8 ± 124	728.35 ± 38.46	1301.2 ± 91.06	2220.6 ± 145.78
	%	59.803%*	24.373%	120.613%*	31.910%*	213.663%*
Sixth week	*C*	1477.32 ± 44.6	1045.91 ± 104.16	667.4 ± 60.66	940.55 ± 15.94	1889.22 ± 122.69
	T	2142.7 ± 164.11	1362.2 ± 67.58	764.52 ± 43.02	1400.6 ± 107.72	2088 ± 65.2
	%	45.037%*	30.244%*	14.552%	48.908%*	10.522%
Seventh week	*C*	1723.2 ± 189.57	963.25 ± 99.51	819.02 ± 79.27	1002.18 ± 89.29	1562.57 ± 66.25
	T	2161.9 ± 131.03	1386.4 ± 110.83	825.99 ± 35.76	1382.2 ± 46.94	2240.7 ± 53.62
	%	25.458%	43.927%*	0.851%	37.921%*	43.397%*
Eighth week	*C*	1636.86 ± 175.06	933.67 ± 86.38	347.65 ± 17.44	1084.6 ± 52.37	1034.83 ± 98.03
	T	2351.9 ± 121.2	1619.5 ± 114.48	873.61 ± 72.99	1626.2 ± 56.91	2412.5 ± 76.17
	%	43.685%*	73.453%*	151.289%*	49.932%*	133.132%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control ($C = 6$) and treated ($T = 6$) animals.

* Significant at ($P < 0.05$).

Table 6 represents the i.p. injection of 0.00065 mg/g iron ion that caused a significant increase in calcium ion (Ca^{+2}) content in cerebellum at the third, fourth, fifth, sixth, and eighth weeks of the experiment, in striatum significant increase in calcium ion concentration was noticed at the fourth, sixth, seventh, and eighth weeks of the experiment, in cerebral cortex significant elevation in calcium ion content was noticed at the third, fourth, fifth, and eighth weeks of the experiment, while increment in calcium ion was noticed in the hypothalamus area at the fifth week and persists till the end of the experiment, in the brain stem increment of the calcium ion concentration was occurred in the third, fourth, fifth,seventh, and eighth weeks of injection. The maximum increase was found in cerebral cortex (+151.29%) after the eighth week of treatment.

The i.p. injection of 0.00065 mg/g iron ion for eight weeks induced no change in potassium ion (K^+) content in all tested brain areas of the adult male albino mice at all experimental periods except in cerebral cortex at the fifth week of injection (Table 7) where it caused increase in the potassium ion content.

As illustrated in (Table 8), the i.p. injection of 0.00065 mg/g iron ion for eight weeks caused a significant increase in sodium (Na^+) content at the fifth week till the eighth week in cerebellum, striatum and cerebral cortex brain areas, while in hypothalamus significant increase in the sodium ion content was noticed at the third week and persists till the end of the experiment, in brain stem area significant increment of sodium was observed at the second, sixth, seventh, and eighth weeks of injection. The maximum increase was found in hypothalamus (+89.37%) after the eighth week.

As demonstrated in (Table 9), the i.p. injection of 0.00065 mg/g iron ion for eight weeks induced a significant increase in iron ion content in cerebellum and brain stem at the third week and persist till the end of experiment, in striatum significant increase in iron ion content was observed from the first week of injection and persists till the eighth week of injection, while in hypothalamus brain area the significant elevation in iron ion content was noticed at the second week of injection and persists till the end of the experiment, finally in cerebral cortex area iron ion content increases significantly at the fourth week and this increment persists till the end of the experiment. The maximum increase was found in striatum (+162.834%) after the sixth week of treatment.

The i.p. injection of 0.00065 mg/g iron ion for eight weeks induced no change in aluminum ion (Al) content in all tested brain areas of the adult male albino mice at all experimental periods except in cerebellum and cerebral cortex at second week, in striatum at the seventh week and brain stem at the first week of injection (Table 10) where it caused significant increase in aluminum content in brain stem and significant decrease in aluminum content of striatum.

Table 11 demonstrates the i.p. injection of 0.0013 mg/g silicon ion for eight weeks that induced no change in the total calcium ion (Ca^{+2}) content at most the experimental times in all tested brain areas except in the cerebral cortex, a significant decrease in calcium ion content was observed at the second week of injection, and midbrain where significant decrease was noticed at the second and fifth weeks of injection.

The i.p. injection of 0.0013 mg/g silicon ion for eight weeks induced no change in potassium ion (K^+) content in all tested brain areas of the adult male albino mice at all experimental periods except in striatum at second week of injection as shown in (Table 12) where a significant decrease was observed.

Also, the i.p. injection of 0.0013 mg/g silicon ion for eight weeks induced no change in sodium (Na^+) content in all tested brain areas of the adult male albino mice at all experimental periods except in striatum at second week of injection as shown in (Table 13) where a significant decrease was observed.

As illustrated in Table 14, the i.p. injection of 0.0013 mg/g silicon ion induced no change in the total content of iron ion (Fe^{+3}) in different brain areas of the adult male albino mice at all experimental periods except in striatum at second week of injection.

As shown in (Table 15), the i.p. injection of 0.0013 mg/g silicon ion for eight weeks induced no change in aluminum (Al^{+3}) content at most tested brain areas of the adult male albino mice at all experimental periods except in cerebellum at second week, in striatum at first, second, third and fifth week where a significant decrease in

Table 7
Effect of chronic i.p. injection of iron ion (0.00065 mg/g) on total content of potassium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	4956.12 ± 496.48	1174.59 ± 188.93	3162.15 ± 267.03	4062.53 ± 448.42	4099.29 ± 307.14
	T	4972.7 ± 289.32	1286.9 ± 90.32	3060 ± 279.64	3880.6 ± 238.46	4011.4 ± 207.13
	%	0.334%	9.563%	−3.230%	−4.479%	−2.145%
Second week	*C*	5405.84 ± 348.22	1142.13 ± 31.99	3327.12 ± 297.98	4234.88 ± 270.3	4063.45 ± 213.37
	T	5024.5 ± 193.92	1111.3 ± 74.81	3256.2 ± 46.41	3877.6 ± 262.89	4005.9 ± 115.37
	%	−7.054%	−2.697%	−2.133%	−8.436%	−1.416%
Third week	*C*	4964.87 ± 247.36	1100.23 ± 72.42	3023.82 ± 54.9	4056.14 ± 247.89	3884.96 ± 416.59
	T	4828.1 ± 253.42	1172.3 ± 82.82	3145.3 ± 140.44	4172.4 ± 271	4005.8 ± 182.28
	%	−2.754%	6.552%	4.017%	2.865%	3.110%
Fourth week	*C*	5076.35 ± 307.18	1198.74 ± 91.71	3374.938 ± 71.53	4065.48 ± 315.56	4113.51 ± 165.86
	T	4626.2 ± 218.59	1082.6 ± 41.03	3414.7 ± 108.29	4189.6 ± 303.16	4136.4 ± 258.44
	%	−8.867%	−9.689%	1.179%	3.054%	0.557%
Fifth week	*C*	4860.11 ± 482.79	1265.94 ± 68.13	3154.99 ± 78.23	4181.31 ± 131.76	4071.93 ± 161.63
	T	5090.4 ± 180.86	1921.1 ± 309.38	3452.1 ± 40.82	5090.4 ± 180.86	3994.8 ± 196.17
	%	4.738%	51.750%	9.417%*	2.703%	−1.895%
Sixth week	*C*	4906.1 ± 484.59	1137.4 ± 60.03	3145.08 ± 150.72	4483.54 ± 299.66	3785.66 ± 149.81
	T	4673 ± 204.16	1103.4 ± 68.74	3274 ± 97.31	4010.3 ± 171.9	3862.6 ± 189.58
	%	−4.751%	−2.990%	4.099%	−10.556%	2.032%
Seventh week	*C*	5145.12 ± 278.42	965.94 ± 36.37	3062.73 ± 187.45	4282.24 ± 209.58	4133.23 ± 322.54
	T	4808.6 ± 232.4	1196.1 ± 92.72	3179.1 ± 171.71	4272 ± 231.38	3998.8 ± 182.8
	%	−6.540%	23.830%	3.798%	−0.238%	−3.253%
Eighth week	*C*	4819.67 ± 258.73	1013.11 ± 153.17	3095.08 ± 154.02	4209.9 ± 252.18	3847.06 ± 155.75
	T	5110.5 ± 279.97	1032.6 ± 75.79	3167.5 ± 91.81	4003.2 ± 182.76	4215.3 ± 180.63
	%	6.034%	1.922%	2.339%	−4.911%	9.572%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

aluminum ion content was observed and the same was observed in cerebral cortex at first and second week of injection.

Table 16 demonstrates the i.p. injection of 0.0013 mg/g aluminum, 0.0013 mg/g silicon and 0.00065 mg/g iron ions, respectively that induced a significant increase in calcium ion (Ca^{+2}) content in hypothalamus at all experimental periods, in striatum, cerebral cortex and brain stem areas significant increase of calcium ion content was observed at the third week and persists till the end of the experiment, while in cerebellum significant increase of calcium ion content was observed at the second week of injection and persists till eighth week. The maximum increase was found in cerebral cortex (+243.47%) after eighth week of treatment.

The i.p. injection of 0.0013 mg/g aluminum, 0.0013 mg/g silicon and 0.00065 mg/g iron ions, respectively, for eight weeks induced no change in potassium ion (K^+) content in most tested brain areas of the adult male albino mice at all experimental periods except in striatum at first, second, third, fourth, fifth, sixth and seventh weeks of injection where significant decrease in concentration of potassium ion content was observed and also significant decrease in potassium ion content was noticed in cerebellum in second and eighth weeks as shown in Table 17.

Table 8
Effect of chronic i.p. injection of iron ion (0.00065 mg/g) on the total content of sodium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem(μg/g ± S.E.)
First week	*C*	868.27 ± 68.66	1427.98 ± 129.16	490.51 ± 5.22	804.57 ± 70.23	711.48 ± 26.8
	T	907.39 ± 32.33	1535.4 ± 45.56	507.03 ± 9.32	961.65 ± 14.19	771.55 ± 18.37
	%	4.505%	7.525%	3.370%	19.523%	8.443%
Second week	*C*	941.52 ± 47.57	1790.49 ± 136.41	580.46 ± 43	835.71 ± 71.9	688.89 ± 28.58
	T	993.71 ± 61.46	1702 ± 85.26	512.26 ± 16.99	945 ± 49.06	770.19 ± 19.72
	%	5.544%	−4.929%	−11.749%	13.078%	11.803%*
Third week	*C*	904.41 ± 64.97	1636.83 ± 102.35	470.07 ± 27.35	810.02 ± 82.2	725.07 ± 34.33
	T	1107.8 ± 65.22	1862.2 ± 118.94	526.72 ± 29.56	1279.4 ± 45.31	793.04 ± 23.1
	%	22.493%	13.770%	12.051%	57.944%*	9.375%
Fourth week	*C*	963.86 ± 81.39	1980.99 ± 179.79	506.46 ± 25.42	792.88 ± 66.59	729.43 ± 70.88
	T	1151.7 ± 50.86	2023.3 ± 55.45	531.8 ± 22.74	1199.7 ± 24.05	813.49 ± 31.51
	%	19.490%	2.135%	5.003%	51.307%*	11.525%
Fifth week	*C*	851.8 ± 54.12	1520.39 ± 112.89	471.86 ± 17.45	712.5 ± 50.64	709.81 ± 32.45
	T	1269.3 ± 61.06	2159.6 ± 184.02	564.19 ± 21.39	1279.7 ± 63.8	829.49 ± 61.35
	%	49.012%*	42.043%*	19.567%*	79.606%*	16.861%
Sixth week	*C*	924.97 ± 78.61	1440.8 ± 136.95	451.11 ± 28.82	867.5 ± 59.37	699.27 ± 30.27
	T	1218.9 ± 85.78	2136.9 ± 102.02	567.24 ± 27.69	1330.4 ± 73.34	831.28 ± 28.17
	%	31.776%*	48.310%*	25.742%*	53.364%*	18.878%*
Seventh week	*C*	951.85 ± 69.09	1244.7 ± 116.07	468.1 ± 9.7	727.38 ± 64.48	662.28 ± 29.51
	T	1317.4 ± 56.08	2232.9 ± 124.6	559.31 ± 17.75	1334.7 ± 46.85	855.07 ± 13
	%	38.405%*	79.396%*	19.486%*	83.490%*	29.110%*
Eighth week	*C*	804.25 ± 60.75	1409.43 ± 132.82	458.18 ± 24.19	818.43 ± 70.86	647.17 ± 22.42
	T	1481.9 ± 102.46	2215.4 ± 74.87	632.16 ± 12.22	1549.8 ± 70.37	905.39 ± 27.07
	%	84.257%*	57.182%*	37.972%*	89.368%*	39.899%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Table 9
Effect of chronic i.p. injection of iron ion (0.00065 mg/g) on the total content of iron ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	106.99 ± 9.89	88.99 ± 6.65	45.34 ± 4.41	109.45 ± 8.02	114.45 ± 13.9
	T	125.73 ± 12.12	152.42 ± 11.21	48.42 ± 2.4	124.9 ± 7.73	136.35 ± 13.27
	%	17.521%	71.285%*	6.800%	14.113%	19.133%
Second week	*C*	109.72 ± 10.27	93.73 ± 10.89	55.81 ± 5.45	91.97 ± 8.63	112.07 ± 10.94
	T	131.55 ± 9.9	142.83 ± 9.15	48.14 ± 3.08	160.22 ± 13.5	143.85 ± 11.21
	%	19.890%	52.395%*	−13.750%	74.218%*	28.356%
Third week	*C*	118.66 ± 12.47	104.45 ± 5.1	55.29 ± 2.93	116.12 ± 11.73	120.68 ± 9.4
	T	218.8 ± 21.74	145.46 ± 6.67	60.26 ± 2.88	213.89 ± 15.74	171.08 ± 4.65
	%	84.398%*	39.273%*	8.995%	84.196%*	41.760%*
Fourth week	*C*	113.05 ± 7.02	84.67 ± 5.77	52.11 ± 4.49	94.45 ± 8.45	111.31 ± 8.91
	T	141.61 ± 14.1	160.72 ± 11.71	75.52 ± 3.42	172.99 ± 7.7	194.14 ± 9.41
	%	25.255%*	89.834%*	44.921%*	83.145%*	74.424%*
Fifth week	*C*	91.16 ± 8.16	82.79 ± 8.61	42.54 ± 1.27	93.98 ± 5.16	109.75 ± 6.2
	T	222.85 ± 5.29	216.24 ± 19.83	91.145 ± 1.7	211.7 ± 5.7	219.21 ± 14.2
	%	144.457%*	161.175%*	114.272%*	125.251%*	99.733%*
Sixth week	*C*	100.42 ± 10.81	85.15 ± 7.88	51.37 ± 5.35	100.5 ± 11.24	114.93 ± 9.15
	T	164.5 ± 15.04	223.79 ± 21.05	89.52 ± 4.29	191.03 ± 17.52	186.64 ± 16.62
	%	63.812%*	162.834%*	74.255%*	90.084%*	62.421%*
Seventh week	*C*	100.41 ± 6.49	93.53 ± 10.36	43.36 ± 4.23	90.99 ± 3.99	105.35 ± 7.72
	T	244.37 ± 16.84	215.19 ± 19.37	85.5 ± 7.44	195.56 ± 19.38	159.3 ± 13.03
	%	143.368%*	130.085%*	97.167%*	114.928%*	51.207%*
Eighth week	*C*	118.04 ± 11.06	98.37 ± 10.11	40.78 ± 3.77	116.98 ± 8.44	103.9 ± 7.96
	T	307.84 ± 13.44	179.32 ± 16.97	103.57 ± 10.27	218.61 ± 18.35	244.65 ± 9.26
	%	160.798%*	82.288%*	142.088%*	86.882%*	135.478%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

As shown in (Table 18), the i.p. injection of 0.0013 mg/g aluminum, 0.0013 mg/g silicon and 0.00065 mg/g iron ions, respectively, for eight weeks induced a significant increase in sodium (Na^+) content in cerebellum area at the fourth, fifth, sixth, seventh and eighth weeks of injection, while significant increase in sodium ion content was noticed in striatum and cerebral cortex brain areas at the third week of injection and persists till the end of the experiment, in hypothalamus and brain stem areas increment of sodium ion content was observed at the second week of injection and persists till the eighth week of treatment. The maximum increase was found in striatum (+154.77%) after the seventh week of treatment.

As illustrated in (Table 19), the i.p. injection of 0.0013 mg/g aluminum, 0.0013 mg/g silicon and 0.00065 mg/g iron ions, respectively, for eight weeks induced a significant increase during the first four weeks of injection in the cerebral cortex, hypothalamus and brain stem while significant increment persists till the fifth week in cerebellum and striatum. This increment followed by a significant decrease till the end of experimental periods of injection in iron ion content in all tested brain areas of adult male albino mice, in cerebral cortex area at the fourth week possesses non-significant change also at the fifth week in brain stem area no significant change was noticed.

Table 10
Effect of chronic i.p. injection of iron ion (0.00065 mg/g) on the total content of aluminum ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	91.78 ± 8.4	119.53 ± 7.9	28.77 ± 1.5	79.73 ± 6.25	52.63 ± 2.27
	T	98.79 ± 4.66	123.8 ± 2.74	27.7 ± 0.82	96.56 ± 7.29	63.45 ± 3.73
	%	7.64%	3.64%	−3.72%	21.11%	20.55%*
Second week	*C*	83.66 ± 2.12	126.68 ± 6.75	24.12 ± 1.12	62.78 ± 4.36	53.91 ± 3.49
	T	71.75 ± 2.96	117.58 ± 8.57	20.63 ± 0.96	60.86 ± 2.68	50.03 ± 4.26
	%	−14.24%*	−7.18%	−14.44%*	−3.06%	−7.19%
Third week	*C*	73.78 ± 6.32	117 ± 10.95	23.1 ± 2.04	71.14 ± 4.28	51.33 ± 4.69
	T	83.39 ± 5.27	110.68 ± 3.48	24.77 ± 0.96	78.82 ± 4.16	48.23 ± 1.5
	%	13.02%	−5.5%	7.22%	7.99%	−6.04%
Fourth week	*C*	80.1 ± 6.74	113.11 ± 11.92	24.29 ± 1.41	62.55 ± 2.29	49.27 ± 3.21
	T	72.15 ± 3.01	93.04 ± 3.01	26.26 ± 1.45	61.27 ± 2.34	49.19 ± 1.15
	%	−9.92%	−17.74%	8.09%	−2.05%	−0.16%
Fifth week	*C*	80.18 ± 5.16	113.09 ± 7.74	24.79 ± 2.73	71.62 ± 7.14	45.21 ± 3.82
	T	89.09 ± 3.79	110.71 ± 6.8	23.57 ± 1.59	75.83 ± 2.71	45.03 ± 2.99
	%	11.12%	−2.1%	−4.95%	5.58%	−0.39%
Sixth week	*C*	85.16 ± 4.55	114.41 ± 8.09	26.82 ± 1.41	74.95 ± 3.63	51.14 ± 5.29
	T	86.32 ± 5.81	106.8 ± 8.77	28.25 ± 1.47	72.85 ± 3.07	49.36 ± 3.56
	%	1.36%	−6.66%	5.32%	−2.8%	−3.49%
Seventh week	*C*	82.43 ± 7.78	112 ± 2.85	26.92 ± 2.1	68.83 ± 4.62	52.53 ± 5.21
	T	81.36 ± 6.47	97.81 ± 3.23	27.92 ± 2	62.3 ± 4.57	51.92 ± 4.3
	%	−1.29%	−12.67%*	3.73%	−9.48%	−1.16%
Eighth week	*C*	86.14 ± 5.36	118.76 ± 10.62	24.93 ± 2.08	77.28 ± 5.56	54.61 ± 4.88
	T	87.46 ± 5.41	107.71 ± 7.07	26.73 ± 0.82	67.11 ± 4.95	58.75 ± 1.53
	%	1.53%	−9.31%	7.22%	−13.15%	7.59%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Table 11
Effect of chronic i.p. injection of silicon ion (0.0013 mg/g) on the total content of calcium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C.cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	1436.7 ± 103.65	1003.28 ± 93.76	583.8 ± 49.20	1066.1 ± 112.46	1380.86 ± 158.49
	T	1372 ± 88.4	984.13 ± 29.16	520 ± 16.59	999.9 ± 26	1329.7 ± 73.8
	%	−4.51%	−1.91%	−10.93%	−6.21%	−3.7%
Second week	*C*	1473.37 ± 151.91	1054.15 ± 138.06	640.58 ± 18.38	1106.15 ± 95.92	1682.92 ± 99.03
	T	1421.1 ± 77.44	903.84 ± 27.35	528.06 ± 15.05	1007 ± 77.55	1317.1 ± 61.97
	%	−3.55%	−14.26%	−17.57%*	−8.97%	−21.74%*
Third week	*C*	1504.1 ± 159.71	994.5 ± 95.92	402.31 ± 43.47	1077.48 ± 129.36	1150.41 ± 69.79
	T	1459.8 ± 82.59	942.89 ± 62.81	474.28 ± 15.2	1085.6 ± 60.97	1123.8 ± 41.13
	%	−2.94%	−5.19%	17.89%	0.75%	−2.37%
Fourth week	*C*	1323.89 ± 101.44	978.03 ± 89.24	532.79 ± 65.96	1046.23 ± 68.7	1223.84 ± 87.3
	T	1434.8 ± 24.72	1001.3 ± 42.06	521.05 ± 20.23	1093.4 ± 79.14	1182.3 ± 65.84
	%	8.38%	2.38%	−2.2%	4.51%	−3.39%
Fifth week	*C*	1322.07 ± 124.69	1094.96 ± 130.74	330.15 ± 42.42	986.45 ± 55.62	707.97 ± 36.1
	T	1427.9 ± 73	1086.1 ± 47.66	378.18 ± 19.94	978.46 ± 57.16	1282.2 ± 85.72
	%	8%	−0.8%	14.55%	−0.81%	81.11%*
Sixth week	*C*	1477.32 ± 44.6	1045.91 ± 104.16	667.4 ± 60.66	940.55 ± 15.94	1889.22 ± 122.69
	T	1471 ± 54.21	1054.1 ± 21.05	610.83 ± 23.57	1048.3 ± 59.47	1660.6 ± 37.83
	%	−0.43%	0.78%	−8.48%	11.46%	−12.1%
Seventh week	*C*	1723.2 ± 189.57	963.25 ± 99.51	819.02 ± 79.27	1002.18 ± 89.29	1562.57 ± 66.25
	T	1476.7 ± 31.32	942.62 ± 46.72	783.3 ± 25.71	1059.2 ± 87.06	1534.1 ± 64.79
	%	−14.3%	−2.14%	−4.36%	5.69%	−1.82%
Eighth week	*C*	1636.86 ± 175.06	933.67 ± 86.38	347.65 ± 17.44	1084.6 ± 52.37	1034.83 ± 98.03
	T	1430.1 ± 40.06	1004.8 ± 39.87	437.78 ± 22.34	950.49 ± 42.71	1092.6 ± 69.47
	%	−12.63%	7.62%	25.93%*	−12.37%	5.58%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.
* Significant at ($P < 0.05$).

Table 20 represents the effect of i.p. injection of 0.0013 mg/g aluminum, 0.0013 mg/g silicon and 0.00065 mg/g iron ions, respectively, for eight weeks that induced a significant increase in aluminum ion (Al) content in cerebellum and striatum from the third week of treatment till the end of the experiment, in cerebral cortex significant increment was observed at the second week of treatment and persists till the eighth week of treatment, while in hypothalamus and brain stem show significant increase in aluminum ion content all over the experiment periods. The maximum increase was found in hypothalamus (+170.55%) after the eighth week of treatment.

4. Discussion

The route of entry of cement dust in the body is the respiratory tract and/or through the gastrointestinal tract by inhalation or swallowing, respectively. Both routes of entry are exposed to numerous potentially harmful substances in the cement mill environment; in this study intrapretoneal injection was used to ensure that the required dose will be delivered. Aluminum ion, as neurotoxine, effect in this study may be interpreted as aluminium and was found to alter glutamate and γ-aminobutrate levels as well as activities of associated enzymes with regional specifity [22]. Cal-

Table 12
Effect of chronic i.p. injection of silicon ion (0.0013 mg/g) on the total content of potassium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	4956.12 ± 496.48	1174.59 ± 188.93	3162.15 ± 267.03	4062.53 ± 448.42	4099.29 ± 307.14
	T	4973.3 ± 292.66	1135.4 ± 70.21	3183.5 ± 79.32	4167.8 ± 285.73	4107.8 ± 175.32
	%	0.35%	−3.34%	0.67%	2.59%	0.21%
Second week	*C*	5405.84 ± 348.22	1142.13 ± 31.99	3327.12 ± 297.98	4234.88 ± 270.3	4063.45 ± 213.37
	T	5413.5 ± 275.84	1014.8 ± 21.4	3330.9 ± 69.95	4119.5 ± 285.97	4085.9 ± 125.18
	%	0.14%	−11.15%*	0.11%	−2.73%	0.55%
Third week	*C*	4964.87 ± 247.36	1100.23 ± 72.42	3023.82 ± 54.9	4056.14 ± 247.89	3884.96 ± 416.59
	T	4903.2 ± 258.01	1039 ± 27.83	3002.2 ± 79.51	4158.2 ± 261.81	4015.3 ± 175.35
	%	−1.24%	−5.57%	−0.71%	2.52%	3.36%
Fourth week	*C*	5076.35 ± 307.18	1198.74 ± 91.71	3374.938 ± 71.53	4065.48 ± 315.56	4113.51 ± 165.86
	T	4864.5 ± 189.48	1079.6 ± 246.79	3233.5 ± 165.23	4246.7 ± 246.79	4081.2 ± 221.83
	%	−4.17%	−9.94%	−4.19%	4.46%	−0.79%
Fifth week	*C*	4860.11 ± 482.79	1265.94 ± 68.13	3154.99 ± 78.23	4181.31 ± 131.76	4071.93 ± 161.63
	T	4923 ± 248.18	1251.5 ± 79.45	3097.3 ± 125.76	4166.3 ± 175.03	4000.8 ± 168.19
	%	1.3%	−1.14%	−1.83%	−0.36%	−1.75%
Sixth week	*C*	4906.1 ± 484.59	1137.4 ± 60.03	3145.08 ± 150.72	4483.54 ± 299.66	3785.66 ± 149.81
	T	4601.3 ± 196.18	1061.3 ± 41.71	3084.3 ± 155.92	4489.1 ± 271.64	3525.8 ± 86.35
	%	−6.21%	−6.69%	−1.93%	0.13%	−6.86%
Seventh week	*C*	5145.12 ± 278.42	965.94 ± 36.37	3062.73 ± 187.45	4282.24 ± 209.58	4133.23 ± 322.54
	T	5194.1 ± 326.03	923.31 ± 50.19	3083.5 ± 96.57	4116.3 ± 367.84	4211.3 ± 118.03
	%	0.95%	−4.41%	0.68%	−3.87%	1.89%
Eighth week	*C*	4819.67 ± 258.73	1013.11 ± 153.17	3095.08 ± 154.02	4209.9 ± 252.18	3847.06 ± 155.75
	T	4882.8 ± 170.17	1030.2 ± 47.61	3155.8 ± 189.5	4383.9 ± 135.39	3505.8 ± 126.91
	%	1.31%	1.69%	1.96%	4.13%	−8.87%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.
* Significant at ($P < 0.05$).

Table 13
Effect of chronic i.p. injection of silicon ion (0.0013 mg/g) on the total content of sodium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	868.27 ± 68.66	1427.98 ± 129.16	490.51 ± 5.22	804.57 ± 70.23	711.48 ± 26.8
	T	831.56 ± 44.01	1442.3 ± 61.92	455.49 ± 27.17	789.7 ± 17.24	721.38 ± 47.61
	%	−4.23%	1%	−7.139%	−1.85%	1.39%
Second week	*C*	941.52 ± 47.57	1790.49 ± 136.41	580.46 ± 43	835.71 ± 71.9	688.89 ± 28.58
	T	905.94 ± 23.31	1422.3 ± 46.86	500.8 ± 22.38	781.37 ± 20.82	619.2 ± 30.29
	%	−3.78%	−20.56%*	−13.72%	−6.5%	−10.12%
Third week	*C*	904.41 ± 64.97	1636.83 ± 102.35	470.07 ± 27.35	810.02 ± 82.2	725.07 ± 34.33
	T	896.69 ± 42.1	1723.3 ± 96.81	439.88 ± 12.97	828.06 ± 47.17	698.89 ± 13
	%	−0.85%	5.28%	−6.42%	2.23%	−3.61%
Fourth week	*C*	963.86 ± 81.39	1980.99 ± 179.79	506.46 ± 25.42	792.88 ± 66.59	729.43 ± 70.88
	T	1063.1 ± 24.12	1840 ± 69.24	494.54 ± 16.48	804.85 ± 43.34	758.92 ± 23.54
	%	10.29%	−7.12%	−2.35%	1.51%	4.04%
Fifth week	*C*	851.8 ± 54.12	1520.39 ± 112.89	471.86 ± 17.45	712.5 ± 50.64	709.81 ± 32.45
	T	880.24 ± 23.07	1535.6 ± 47.69	490.25 ± 14.63	702.37 ± 42.25	704.21 ± 47.75
	%	3.34%	1%	3.9%	−1.42%	−0.79%
Sixth week	*C*	924.97 ± 78.61	1440.8 ± 136.95	451.11 ± 28.82	867.5 ± 59.37	699.27 ± 30.27
	T	890.81 ± 28.19	1441 ± 58.16	432.33 ± 25.75	836.45 ± 34.41	727.37 ± 28.84
	%	−3.7%	0.02%	−4.17%	−3.58%	4.02%
Seventh week	*C*	951.85 ± 69.09	1244.7 ± 116.07	468.1 ± 9.7	727.38 ± 64.48	662.28 ± 29.51
	T	882.73 ± 23.58	1230.5 ± 75.9	457.2 ± 20.22	771.13 ± 40.68	703.11 ± 34.1
	%	−7.26%	−1.14%	−2.33%	6.02%	6.17%
Eighth week	*C*	804.25 ± 60.75	1409.43 ± 132.82	458.18 ± 24.19	818.43 ± 70.86	647.17 ± 22.42
	T	758.99 ± 25.78	1348.1 ± 57.42	472.06 ± 24.45	724.5 ± 49.56	650.78 ± 26.78
	%	−5.63%	−4.35%	3.03%	−11.48%	0.55%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

cium plays a central role in neurotransmitter release, alterations in calcium metabolism and/or utilization could be a central mechanism in Al neurotoxicity [8], and this may be the reason for elevation of calcium during aluminum injection.

Wisniewski et al. [23] subsequently found that injection of A1 into the cisterna magna of rabbits produced axonal swelling and dendritic thickening. Moreover, Wenk and Stemmer [24], measuring A1 by flame atomic absorption spectroscopy, found an increase in A1 in both brain (tenfold) and liver (33%) in rats consuming suboptimal amounts of Zn and supplemental dietary Al. A1 could bind to bovine brain calmodulin and alter its structure so that it could not bind Ca^{2+} and participate in the second messenger system. It was found that Al may inhibit bovine caudate acetylcholinesterase and that this effect may be modified by levels of tissue and cytoplasmic Ca^{2+} [23] and this supports the study findings for elevation of aluminum concentrations in various brain areas and subsequently calcium ions also during aluminum injection.

Rao [25] demonstrated that the direct effect of aluminum ion depends on Al binding to different brain cells namely astrocytes, neural cells and synaptosomes, but interacts more with the former causing inhibition of membrane-bound Na^+, K^+, Ca^{2+} ATPase activity and these enzymatic disturbance would result in cellular

Table 14
Effect of chronic i.p. injection of silicon ion ion (0.0013 mg/g) on the total content of iron ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem(μg/g ± S.E.)
First week	*C*	106.99 ± 9.89	88.99 ± 6.65	45.34 ± 4.41	109.45 ± 8.02	114.45 ± 13.9
	T	96.48 ± 5.32	77.36 ± 4.5	39.4 ± 2.6	109.29 ± 8.03	135.11 ± 5.91
	%	−9.82%	−13.07%	−13.1%	−0.15%	18.06%
Second week	*C*	109.72 ± 10.27	93.73 ± 10.89	55.81 ± 5.45	91.97 ± 8.63	112.07 ± 10.94
	T	91.83 ± 4.37	52 ± 9.08	46.28 ± 4.01	104.39 ± 8.39	106.24 ± 7.37
	%	−16.31%	−44.52%*	−17.08%	13.51%	−5.2%
Third week	*C*	118.66 ± 12.47	104.45 ± 5.1	55.29 ± 2.93	116.12 ± 11.73	120.68 ± 9.4
	T	92.52 ± 8.21	91.11 ± 2.56	50.16 ± 2.11	115.14 ± 11.29	102.99 ± 7.41
	%	−22.03%	−12.77%	−9.27%	−0.85%	−14.66%
Fourth week	*C*	113.05 ± 7.02	84.67 ± 5.77	52.11 ± 4.49	94.45 ± 8.45	111.31 ± 8.91
	T	94.21 ± 7.38	86.83 ± 6.29	48.79 ± 1.39	113.88 ± 4.79	106.6 ± 5.3
	%	−16.67%	2.55%	−6.36%	20.57%	−4.23%
Fifth week	*C*	91.16 ± 8.16	82.79 ± 8.61	42.54 ± 1.27	93.98 ± 5.16	109.75 ± 6.2
	T	96.47 ± 7.04	96.68 ± 7.05	45.8 ± 1.82	96.47 ± 7.64	109.32 ± 8.83
	%	5.83%	16.78%	7.67%	2.65%	−0.4%
Sixth week	*C*	100.42 ± 10.81	85.15 ± 7.88	51.37 ± 5.35	100.5 ± 11.24	114.93 ± 9.15
	T	92.46 ± 8.81	88.96 ± 6.39	48.67 ± 3.82	100.55 ± 10.02	120.77 ± 11.74
	%	−7.93%	4.48%	−5.25%	0.05%	5.08%
Seventh week	*C*	100.41 ± 6.49	93.53 ± 10.36	43.36 ± 4.23	90.99 ± 3.99	105.35 ± 7.72
	T	84.34 ± 7.11	82.88 ± 4.17	41.69 ± 3.14	106.24 ± 9.96	111.56 ± 7.54
	%	−16%	−11.38%	−3.86%	16.76%	5.9%
Eighth week	*C*	118.04 ± 11.06	98.37 ± 10.11	40.78 ± 3.77	116.98 ± 8.44	103.9 ± 7.96
	T	100.3 ± 6.45	90.5 ± 5.69	43.82 ± 3.03	105.71 ± 8.19	103.47 ± 5.3
	%	−15.03%	−8%	2.41%	−10.66%	−0.41%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Table 15
Effect of chronic i.p. injection of silicon ion (0.0013 mg/g) on the total content of aluminum ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	91.78 ± 8.4	119.53 ± 7.9	28.77 ± 1.5	79.73 ± 6.25	52.63 ± 2.27
	T	92.77 ± 6.32	91.6 ± 2.07	24.75 ± 0.73	78.78 ± 3	52.05 ± 1.54
	%	1.07%	−23.37%*	−13.96%*	−1.19%	−1.11%
Second week	*C*	83.66 ± 2.12	126.68 ± 6.75	24.12 ± 1.12	62.78 ± 4.36	53.91 ± 3.49
	T	60.73 ± 2.47	93.47 ± 7.54	20.01 ± 0.69	56.39 ± 5.11	48.38 ± 3.25
	%	−27.41%*	−26.22%*	−17.03%*	−10.18%	−10.25%
Third week	*C*	73.78 ± 6.32	117 ± 10.95	23.1 ± 2.04	71.14 ± 4.28	51.33 ± 4.69
	T	74.54 ± 3.14	85.373 ± 5.3138	20.98 ± 1.73	66.02 ± 4.42	42.63 ± 3.71
	%	1.03%	−27.106%*	−9.18%	−7.2%	−16.96%
Fourth week	*C*	80.1 ± 6.74	113.11 ± 11.92	24.29 ± 1.41	62.55 ± 2.29	49.27 ± 3.21
	T	78.66 ± 4.42	106.21 ± 3.45	24.31 ± 1.59	78.11 ± 6.65	50.53 ± 4.97
	%	−1.79%	−6.1%	0.042%	24.87%	2.55%
Fifth week	*C*	80.18 ± 5.16	113.09 ± 7.74	24.79 ± 2.73	71.62 ± 7.14	45.21 ± 3.82
	T	77.5 ± 2.56	90.98 ± 4.41	25.56 ± 2.28	71.35 ± 6.96	52.54 ± 5.17
	%	−3.35%	−19.55%*	3.08%	−0.38%	16.21%
Sixth week	*C*	85.16 ± 4.55	114.41 ± 8.09	26.82 ± 1.41	74.95 ± 3.63	51.14 ± 5.29
	T	82.19 ± 6.43	121.26 ± 10.5	26.24 ± 2.54	79.22 ± 6.3	52.53 ± 3.96
	%	−3.52%	5.99%	−2.18%	5.71%	2.72%
Seventh week	*C*	82.43 ± 7.78	112 ± 2.85	26.92 ± 2.1	68.83 ± 4.62	52.53 ± 5.21
	T	79.97 ± 2.7	120.65 ± 5.94	26.05 ± 1.66	87.29 ± 2.69	55.65 ± 5.53
	%	−2.98%	7.72%	−3.21%	26.83%	5.95%
Eighth week	*C*	86.14 ± 5.36	118.76 ± 10.62	24.93 ± 2.08	77.28 ± 5.56	54.61 ± 4.88
	T	74.7 ± 6.43	114.31 ± 17.55	25.55 ± 1.91	76.79 ± 4.25	54.59 ± 4.42
	%	−13.28%	−3.75%	2.49%	−13.28%	−0.04%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

alterations and may be death. Also aluminum interference with calcium binding to calmodulin which may cause an elevated concentration of calcium in the brains of aluminum-treated animals [26], also supports the study findings in elevation of sodium and calcium concentration in brain areas versus aluminum injection.

From the present study, it is clear that chronic administration of 0.0013 mg/g aluminum ion caused a significant increase in aluminum, calcium and sodium ions in all the tested brain areas of the adult male albino mice in most experimental periods. These results are in agreement with the previous reports by Rao [25] and Abd El Rahman [6], on the other hand chronic administration of 0.0013 mg/g aluminum ion caused a significant decrease in iron ion in all the tested brain areas of the adult male albino mice in most experimental periods. These results are in agreement with the previous reports by Roskams and Connor that transferrin (Tf) may have been defined as an iron transporter protein mainly because of the relatively high abundance of iron in the circulation in relation to these other ions. If this balance were to change because of some environmental, nutritional, or disease factor, Tf could transport these other metal ions and deposit them intracel-

Table 16
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g), silicon ion (0.0013 mg/g) and iron ion (0.00065 mg/g) on the total content of calcium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C.cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	1436.7 ± 103.65	1003.28 ± 93.76	583.8 ± 49.20	1066.1 ± 112.46	1380.86 ± 158.49
	T	1954.4 ± 226.33	1082 ± 57.21	600 ± 34.33	1444.8 ± 87.15	1408.6 ± 125.03
	%	36.03%	+7.84%	+2.78%	35.53%*	2.01%
Second week	*C*	1473.37 ± 151.91	1054.15 ± 138.06	640.58 ± 18.38	1106.15 ± 95.92	1682.92 ± 99.03
	T	2212.3 ± 51.88	1171.7 ± 63.03	813.7 ± 68.84	1467.4 ± 109.04	2046.1 ± 305.62
	%	+50.15%*	+11.15%	27.03%	32.66%*	21.58%
Third week	*C*	1504.1 ± 159.71	994.5 ± 95.92	402.31 ± 43.47	1077.48 ± 129.36	1150.41 ± 69.79
	T	2678.3 ± 132.08	1365.8 ± 95.21	868.07 ± 59.8	1548.5 ± 121.76	2186.7 ± 175.18
	%	+78.07%*	+37.34%*	115.77%*	43.72%*	90.08%*
Fourth week	*C*	1323.89 ± 101.44	978.03 ± 89.24	532.79 ± 65.96	1046.23 ± 68.7	1223.84 ± 87.3
	T	2809.4 ± 172.28	1446.8 ± 59.25	901.84 ± 59.2	1551.9 ± 65.94	2335.5 ± 128.96
	%	+112.21%*	+47.93%*	69.27%*	48.33%*	90.84%*
Fifth week	*C*	1322.07 ± 124.69	1094.96 ± 130.74	330.15 ± 42.42	986.45 ± 55.62	707.97 ± 36.1
	T	3115.9 ± 183.35	1539.3 ± 68.94	941.41 ± 51	1634.7 ± 136.03	2378.9 ± 94.13
	%	+135.69%*	+40.58%*	185.15%*	65.72%*	236.02%*
Sixth week	*C*	1477.32 ± 44.6	1045.91 ± 104.16	667.4 ± 60.66	940.55 ± 15.94	1889.22 ± 122.69
	T	3293.1 ± 242.85	1620 ± 66.82	1147.6 ± 40.98	1755.7 ± 191.54	2477 ± 221.17
	%	+122.91%*	+54.89%*	+71.95%*	86.67%*	31.12%*
Seventh week	*C*	1723.2 ± 189.57	963.25 ± 99.51	819.02 ± 79.27	1002.18 ± 89.29	1562.57 ± 66.25
	T	2956.6 ± 304.05	1839.9 ± 5.71	1202 ± 56.04	2016.6 ± 170	2623.6 ± 228.56
	%	71.58%*	90.99%*	+46.76%*	+101.23%*	67.9%*
Eighth week	*C*	1636.86 ± 175.06	933.67 ± 86.38	347.65 ± 17.44	1084.6 ± 52.37	1034.83 ± 98.03
	T	3297.9 ± 188.2	2130.4 ± 65.2	1194.1 ± 62.71	1951.8 ± 259	2733.5 ± 147.22
	%	+101.48%*	+128.18%*	243.47%*	79.96%*	164.15%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Table 17
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g), silicon ion (0.0013 mg/g), and iron ion (0.00065 mg/g) on the total content of potassium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	4956.12 ± 496.48	1174.59 ± 188.93	3162.15 ± 267.03	4062.53 ± 448.42	4099.29 ± 307.14
	T	4147.1 ± 294.58	680.53 ± 43.54	3008.6 ± 146.96	5101.4 ± 420.38	3864.9 ± 254.73
	%	−16.32%	−42.06%*	−4.86%	25.57%	−5.72%
Second week	*C*	5405.84 ± 348.22	1142.13 ± 31.99	3327.12 ± 297.98	4234.88 ± 270.3	4063.45 ± 213.37
	T	4311 ± 181.98	670.82 ± 76.87	3224.7 ± 99.6	4588.7 ± 252.23	4318.2 ± 330.74
	%	−20.25%*	−41.27%*	−3.08%	8.36%	6.27%
Third week	*C*	4964.87 ± 247.36	1100.23 ± 72.42	3023.82 ± 54.9	4056.14 ± 247.89	3884.96 ± 416.59
	T	4468.7 ± 466	960.77 ± 134.82	3080.2 ± 238.4	4002.4 ± 548.24	4259.6 ± 319.72
	%	−9.99%	−12.68%*	1.87%	−1.32%	9.64%
Fourth week	*C*	5076.35 ± 307.18	1198.74 ± 91.71	3374.938 ± 71.53	4065.48 ± 315.56	4113.51 ± 165.86
	T	4469.5 ± 386.01	927.54 ± 24.05	3554.1 ± 249.95	4062.7 ± 342.32	4539.2 ± 126.17
	%	−11.95%	−22.62%*	5.31%	−0.07%	10.35%
Fifth week	*C*	4860.11 ± 482.79	1265.94 ± 68.13	3154.99 ± 78.23	4181.31 ± 131.76	4071.93 ± 161.63
	T	4155.8 ± 255.52	841.5 ± 56.29	2791.6 ± 234.09	3862.3 ± 122.7	3945.9 ± 254.42
	%	−14.49%	−33.53%*	−11.52%	−7.63%	−3.1%
Sixth week	*C*	4906.1 ± 484.59	1137.4 ± 60.03	3145.08 ± 150.72	4483.54 ± 299.66	3785.66 ± 149.81
	T	4054.7 ± 295.35	857.82 ± 67.92	2855.3 ± 165.16	4671.9 ± 372.69	4115.4 ± 172.96
	%	−17.35%	−24.58%*	−9.21%	4.2%	8.71%
Seventh week	*C*	5145.12 ± 278.42	965.94 ± 36.37	3062.73 ± 187.45	4282.24 ± 209.58	4133.23 ± 322.54
	T	5760.3 ± 493.49	681.85 ± 25.67	3268.4 ± 250.93	4105.8 ± 418.11	4410.5 ± 460.09
	%	11.96%	−29.41%*	6.72%	−4.12%	6.71%
Eighth week	*C*	4819.67 ± 258.73	1013.11 ± 153.17	3095.08 ± 154.02	4209.9 ± 252.18	3847.06 ± 155.75
	T	3960.7 ± 123.89	807.64 ± 46.11	2695.3 ± 81.44	5086.9 ± 635.21	3448.9 ± 204.07
	%	−17.82%*	−20.28%	−12.92%	20.83%	−10.35%

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

lularly instead of or in addition to iron. Because CNS neurons (in which Al^{3+} accumulation is most marked) are terminally differentiated, the Al^{3+} transported into these cells will accumulate unless specific systems are available to remove them [27]. This demonstrated the illustrated results where iron concentration decreased versus aluminum injection due to the affinity of transferrin to Al^{3+}.

From the present results, it is clear that chronic administration of 0.00065 mg/g iron ion caused a significant increase in iron ion, calcium, and sodium ions in all the tested brain areas of the adult male albino mice in most experimental periods. These results are in agreement with the previous reports by Palmer et al. [28]. On the other hand, there was a non-significant change in potassium and aluminum ions.

Evidence so far suggests sub-sensitivity of striatal dopamine neurotransmission. By contrast the selective increase in free iron ion in the sub-stantia nigra pars compacta of parkinsonian brains is thought to initiate oxidative stress, from iron-ion-induced liberation of cytotoxic oxygen free radicals. Such radicals are known to

Table 18
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g), silicon ion (0.0013 mg/g), and iron ion (0.00065 mg/g) on the total content of sodium ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	868.27 ± 68.66	1427.98 ± 129.16	490.51 ± 5.22	804.57 ± 70.23	711.48 ± 26.8
	T	1022.2 ± 43.75	1636.1 ± 127.1	485.83 ± 17.35	1066.3 ± 119.93	739.27 ± 61.92
	%	+17.73%	14.58%	−0.95%	32.53%	3.91%
Second week	*C*	941.52 ± 47.57	1790.49 ± 136.41	580.46 ± 43	835.71 ± 71.9	688.89 ± 28.58
	T	1115.7 ± 38.49	2039.7 ± 59.25	645.8 ± 34.58	1118.5 ± 43.78	842.29 ± 46.26
	%	+18.5%	+13.92%	+11.26%	33.84%*	22.27%*
Third week	*C*	904.41 ± 64.97	1636.83 ± 102.35	470.07 ± 27.35	810.02 ± 82.2	725.07 ± 34.33
	T	1077.3 ± 96.53	2238.7 ± 51.86	723.99 ± 44.88	1139.1 ± 78.35	808.17 ± 61.21
	%	+19.12%	+36.77%*	+54.02%*	40.63%*	25.25%*
Fourth week	*C*	963.86 ± 81.39	1980.99 ± 179.79	506.46 ± 25.42	792.88 ± 66.59	729.43 ± 70.88
	T	1309.3 ± 77.17	2448.7 ± 55.45	800.09 ± 44.1	1177.3 ± 68.76	970.6276.88
	%	+35.84%*	+23.61%*	+57.98%*	48.48%*	33.06%*
Fifth week	*C*	851.8 ± 54.12	1520.39 ± 112.89	471.86 ± 17.45	712.5 ± 50.64	709.81 ± 32.45
	T	1575.5 ± 55.02	2668.9 ± 93.82	929.88 ± 40.22	1225.8 ± 76.35	950.94 ± 85.47
	%	+84.96%*	+75.54%*	+97.07%*	72.05%*	33.97%*
Sixth week	*C*	924.97 ± 78.61	1440.8 ± 136.95	451.11 ± 28.82	867.5 ± 59.37	699.27 ± 30.27
	T	1772.6 ± 61.79	2737.3 ± 133.68	1049.1 ± 42.86	1227.3 ± 113.55	970.13 ± 55.22
	%	+91.64%*	+89.99%*	+132.55%*	41.47%*	38.73%*
Seventh week	*C*	951.85 ± 69.09	1244.7 ± 116.07	468.1 ± 9.7	727.38 ± 64.48	662.28 ± 29.51
	T	1588 ± 89.09	3171.1 ± 145.52	915.85 ± 71.42	1251.3 ± 97.84	1018.5 ± 86.94
	%	66.83%*	+154.77%*	95.65%*	72.04%*	53.79%*
Eighth week	*C*	804.25 ± 60.75	1409.43 ± 132.82	458.18 ± 24.19	818.43 ± 70.86	647.17 ± 22.42
	T	1845.3 ± 23.88	3269.8 ± 118.89	1102.4 ± 17.68	1448.6 ± 65.06	1022.3 ± 39.14
	%	+129.44%*	+131.99%*	+140.6%*	76.99%*	57.96%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

Table 19
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g), silicon ion (0.0013 mg/g), and iron ion (0.00065 mg/g) on the total content of iron ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	106.99 ± 9.89	88.99 ± 6.65	45.34 ± 4.41	109.45 ± 8.02	114.45 ± 13.9
	T	249.29 ± 31.04	237.8 ± 23.07	181.54 ± 13.35	343.48 ± 21.51	318.26 ± 23.95
	%	133.02%*	167.23%*	300.43%*	213.82%*	178.08%*
Second week	*C*	109.72 ± 10.27	93.73 ± 10.89	55.81 ± 5.45	91.97 ± 8.63	112.07 ± 10.94
	T	272.46 ± 12.05	228.04 ± 20.43	181.01 ± 10.68	225.57 ± 11.65	365.55 ± 19.45
	%	148.31%*	143.3%*	224.33%*	145.28%*	226.19%*
Third week	*C*	118.66 ± 12.47	104.45 ± 5.1	55.29 ± 2.93	116.12 ± 11.73	120.68 ± 9.4
	T	280.97 ± 24.05	251.2 ± 27.76	168.02 ± 15.77	213.88 ± 11.81	294.91 ± 21.44
	%	136.79%*	140.51%*	408.2%*	84.19%*	144.37%*
Fourth week	*C*	113.05 ± 7.02	84.67 ± 5.77	52.11 ± 4.49	94.45 ± 8.45	111.31 ± 8.91
	T	148.19 ± 6.8	195.61 ± 16.29	61.7 ± 3.5	152.48 ± 12.07	246.49 ± 5.8
	%	31.08%*	131.04%*	18.42%	61.44%*	121.46%*
Fifth week	*C*	91.16 ± 8.16	82.79 ± 8.61	42.54 ± 1.27	93.98 ± 5.16	109.75 ± 6.2
	T	123.68 ± 11.01	124.41 ± 9.49	28.06 ± 0.63	58.22 ± 3.76	116.24 ± 8.09
	%	35.67%*	50.26%*	−34.04%*	−38.05%*	5.91%
Sixth week	*C*	100.42 ± 10.81	85.15 ± 7.88	51.37 ± 5.35	100.5 ± 11.24	114.93 ± 9.15
	T	58.72 ± 4.99	56.86 ± 4.36	28.92 ± 1.87	65.14 ± 5.4	78.38 ± 5.11
	%	−41.53%*	−33.22%*	−43.71%*	−35.18%*	−31.81%*
Seventh week	*C*	100.41 ± 6.49	93.53 ± 10.36	43.36 ± 4.23	90.99 ± 3.99	105.35 ± 7.72
	T	66.52 ± 3.76	29.49 ± 2.9	27.58 ± 0.95	54.51 ± 4.95	63.53 ± 5.11
	%	−33.76%*	−68.46%*	−36.4%*	−40.09%*	−39.7%*
Eighth week	*C*	118.04 ± 11.06	98.37 ± 10.11	40.78 ± 3.77	116.98 ± 8.44	103.9 ± 7.96
	T	47.75 ± 3.66	29.8 ± 3.16	25.49 ± 0.74	48.73 ± 3.79	39.5 ± 2.53
	%	−59.55%*	−69.71%*	−40.43%*	−58.34%*	−61.98%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

promote membrane fluidity, alteration in cellular calcium homeostasis, lipid peroxidation and finally cell death in systemic organs [29] and this may clarify the reasons for elevation of calcium ions content during injection of iron. Also evidence indicates that deregulation of brain iron ion metabolism and transport plays a role in mediating neuronal damage [5] as unbound iron ion gains excess to the extracellular space, its uptake by neuronal cells is paradoxically enhanced by increased level of intracellular iron and calcium ions [28]. And this is another support for this study findings during iron injection explaining the elevation of calcium ions.

In this study, chronic administration of 0.0013 mg/g silicon ion caused a non-significant change in calcium, potassium, sodium, aluminum and iron ions in all the tested brain areas of the adult male albino mice in most experimental periods, this may indicates that silicon ions could not be hazardous solely.

Table 20
Effect of chronic i.p. injection of aluminum ion (0.0013 mg/g), silicon ion (0.0013 mg/g), and iron ion (0.00065 mg/g) on the total content of aluminum ion in the different brain areas of the adult male albino mice.

Weeks		Cerebellum (μg/g ±± S.E.)	Striatum (μg/g ± S.E.)	C. cortex (μg/g ± S.E.)	Hypothalamus (μg/g ± S.E.)	Brain stem (μg/g ± S.E.)
First week	*C*	91.78 ± 8.4	119.53 ± 7.9	28.77 ± 1.5	79.73 ± 6.25	52.63 ± 2.27
	T	95.5 ± 7.65	109.87 ± 7.83	34.9 ± 2.34	121.03 ± 7.7	62.02 ± 2.88
	%	4.05%	−8.08%	21.33%	51.79%*	17.83%*
Second week	*C*	83.66 ± 2.12	126.68 ± 6.75	24.12 ± 1.12	62.78 ± 4.36	53.91 ± 3.49
	T	103.29 ± 10.38	117.01 ± 10.3	38.98 ± 2.02	131.86 ± 13.43	70.55 ± 4.9
	%	23.46%	−7.64%	61.63%*	110.04%*	30.87%*
Third week	*C*	73.78 ± 6.32	117 ± 10.95	23.1 ± 2.04	71.14 ± 4.28	51.33 ± 4.69
	T	112.07 ± 4.55	162.51 ± 16.83	42.11 ± 3.16	138.66 ± 8.43	80.22 ± 4.89
	%	51.89%*	38.75%*	82.26%*	94.92%*	56.28%*
Fourth week	*C*	80.1 ± 6.74	113.11 ± 11.92	24.29 ± 1.41	62.55 ± 2.29	49.27 ± 3.21
	T	121.74 ± 11.5	160.69 ± 7.06	52.13 ± 4.21	146.45 ± 9.37	88.78 ± 3.97
	%	51.99%*	42.06%*	114.57%*	134.15%*	80.17%*
Fifth week	*C*	80.18 ± 5.16	113.09 ± 7.74	24.79 ± 2.73	71.62 ± 7.14	45.21 ± 3.82
	T	124.83 ± 10.57	155.8 ± 12.19	53.08 ± 2.11	154.64 ± 7.47	90.29 ± 6.29
	%	55.7%*	37.77%*	114.12%*	115.9%*	99.7%*
Sixth week	*C*	85.16 ± 4.55	114.41 ± 8.09	26.82 ± 1.41	74.95 ± 3.63	51.14 ± 5.29
	T	136.51 ± 13.85	149.17 ± 6.95	54.57 ± 2.06	166.26 ± 14.91	92.39 ± 5.59
	%	60.29%*	30.38%*	103.44%*	121.84%*	80.65%*
Seventh week	*C*	82.43 ± 7.78	112 ± 2.85	26.92 ± 2.1	68.83 ± 4.62	52.53 ± 5.21
	T	159.31 ± 9.94	155.64 ± 8.03	59.15 ± 3.66	159.71 ± 11.99	98.87 ± 8.87
	%	93.76%*	38.96%*	119.76%*	132.05%*	88.22%*
Eighth week	*C*	86.14 ± 5.36	118.76 ± 10.62	24.93 ± 2.08	77.28 ± 5.56	54.61 ± 4.88
	T	162.15 ± 10.3	171.06 ± 16.75	53.95 ± 1.01	209.07 ± 20.45	97.65 ± 4.92
	%	88.23%*	44.04%*	116.45%*	170.55%*	78.82%*

Control animals were injected with saline (0.9% NaCl). Statistical analysis of results according to independent Student's *t*-test between control (*C* = 6) and treated (*T* = 6) animals.

* Significant at ($P < 0.05$).

On the other hand the present results indicated that chronic administration of 0.0013 mg/g aluminum ion, 0.0013 mg/g silicon ion and 0.00065 mg/g iron ion, respectively caused a higher elevation in calcium, sodium, aluminum ion and iron ion concentrations than the elevation in other groups. These results are in agreement with the previous reports by Parrott et al. [30]. While there was a non-significant change in potassium ion in all the tested brain areas of the adult male albino mice in most experimental periods.

Verstraeten et al. [31] cited that Al enhances Fe^{2+}-mediated lipid oxidation, the observed effects could be a resultant of Al interaction with the bilayer, but also to Fe-induced membrane oxidation with the subsequent loss of poly-unsaturated fatty acids which would make membranes more fluid. Biological membranes are complex, containing a variety of molecules that could be possible targets of, and/or modulators of Al effects. Thus, iron ion initiated lipid peroxidation (LP), whereas aluminum ion did not [32], where aluminum an iron effect on brain is concentration-dependent [27], also aluminum facilitation of iron-mediated lipid peroxidation is dependent on aluminum and iron concentration [32] thus when aluminum and iron are available in appropriate concentrations – as in case of injection of aluminum and iron – it may give the chance for severe damage in the brain areas as it is noticed elevation in aluminum, iron calcium and sodium ions during injection.

Feeding rats with low-silicon diets with supplemental A1 increased brain Al [33,34]. Senile plaques are a neuropathological feature of the ageing brain, they occur in large numbers in Alzheimer's disease. Energy-dispersive X-ray microprobe analysis of isolated cores and plaques in situ from patients with Alzheimer's disease has shown co-localization of high concentrations of aluminum ion (4–19%) and silicon ion (6–24%) at the centre of the core. The presence of aluminum ion as aluminum silicates has been confirmed using solid-state 27 Al nuclear magnetic resonance. This findings provides a link with the other major neuropathological picture of Alzheimer disease, the neurofibrilary tangle-bearing neurons, which were high intracellular levels of Al and silicon ion (Si) have also been reported. The focal deposition of this element may be an early and essential factor in the pathogenesis of Alzheimer type changes, reflecting an increased exposure to aluminum ion [35]. These evidences come in agreement and support of the findings present for the group of mice injected by aluminum, silicon and iron.

Hydrocephalus was induced in three-week old rats by kaolin (hydrated aluminum silicate) injection into the cisterna magna. Parietal cerebrum and striatum content of monoamine neurotransmitters and amino acids were assayed by high performance liquid chromatography (HPLC), one, two, or four weeks after induction of hydrocephalus. Increased levels of cerebral aspartate and glutamate suggest that there is the potential for excitatory neurotoxicity. Cerebral concentrations of norepinephrine and serotonin, and its metabolites 5-hydroxyindolacetic acid (5-HIAA) were increased at. Dopamine and its metabolite 3.4-Dihydroxyphenylacetic acid (DOPAC) were transiently diminished in the striatum. It was concluded that the effect of hydrocephalus on amino acids and monoamines varies regionally. Due to increased water content, there may be dilution effects in whole tissue; therefore, it is important to make determinations on the basis of protein content. The subsequent rise for Ca^{2+} ion concentration stimulates the release of neurotransmitter into the synaptic cleft, which diffuses across this narrow gap and binds to receptors located on the postsynaptic neuronal membrane [30]; this may give interpretation for the present results of elevation of calcium in various brain areas through the period of injection as a result of administration of aluminum and silicon ions.

5. Conclusion

From the present results and previous studies, it could be concluded that the neurotoxicity which was caused by different cement components may be, in part, due to the elevation in glutamate which leads to increase in the intracellular of calcium concentration and the inhibition of membrane-bound Na^+, K^+, Ca^{2+} ATPase activity which lead to cellular alterations and may be death. So long-term exposure to cement components as environmental pollutants may lead to neurodegenerative diseases.

6. Recommendations

1. Enrolment of neurodegenerative disease in the list of occupational diseases.
2. Forcing cement factories to take the control measures that ensure minimizing the environmental exposure to cement dust.
3. Cement factories have to make annual statistics about the workers' health during service and after retiring.
4. Minimizing the threshold limit value allowed to a safer limit taking in consideration the accumulative and long run effect.

References

[1] I. Marlowe, D. Mansfield, Environmental, health and safety performance improvement. world business council for sustainable development, Substudy 10 (2002).
[2] S.A. Meo, Health hazards of cement dust, Saud. Med. J. 25 (9) (2004) 1153–1159.
[3] S. Short, E.L. Petsonk, Non-fibrous inorganic dusts, in: P. Harber, M.B. Schenker, R. John (Eds.), Occupational and Environmental Respiratory Disease, Balmes Mosby, London, 1996, p. 356.
[4] G.J. Brewer, Iron ion and copper toxicity in diseases of aging, particularly atherosclerosis and alzheimer's disease, Exp. Biol. Med. 232 (2007) 323–335.
[5] M.H. Selim, R.R. Ratan, The role of iron ion neurotoxicity in ischemic stroke, Agin. Res. Rev. 3 (2004) 345–353.
[6] S.S. Abd El-Rahman, Neuropathology of aluminum ion toxicity in rats (glutamate and GABA impairment), Pharmacol. Res. 47 (2003) 189–194.
[7] B. Nehru, P. Anand, Oxidative damage following chronic aluminum ion exposure in adult and pup rat brains, J. Trac. Elem. Med. Biol. 19 (2005) 203–208.
[8] S.V. Verstraeten, L. Aimo, P.I. Oteiza, Aluminium and lead molecular mechanisms of brain toxicity, Arch. Toxicol. 82 (2008) 789–802.
[9] A.K. Malekshah, Z. Torabizadeh, F. Naghshwar, Developmental toxicity of aluminum ion from high doses of $AlCl_3$ in mice, J. Appl. Res. 5 (2005) 4.
[10] A.A. Fyiad, Aluminium Toxicity, Oxidative damage reduction by melatonin in rats, J. Appl. Sci. Res. 3 (10) (2007) 1210–1217.
[11] F. Al-Hashem, Camel's milk protects against aluminum chloride-induced toxicity in the liver and kidney of white albino rats, Am. J. Biochem. Biotech. 5 (3) (2009) 98–109.
[12] K. Takaya, Intranuclear silicon ion detection in a subcutaneous connective tissue cell by energy-dispersive X-ray microanalysis using fresh air-dried spread, J. Histochem. Cytochem. 23 (9) (1975) 681–685.
[13] R.A. Goyer, T.W. Clarkson, Toxic Effects of Metals, in: C.D. Klaassen (Ed.), Casarett and Doull's Toxicology the Basic Science of Poisons, McGraw-Hill, New York, 2001, pp. 811–867.
[14] D.J. Osborn, I. Helmy, The contemporary land mammals of Egypt, Fieldia. Zool. 5 (1980) 1–579.
[15] Egyptian labor law no. 12 issue. Decision number 211 issue 2003 for safety limits, conditions and precautions mandatory for fending off physical, mechanical, biological, and chemical hazards and keeping working environment safe, Section 41, Dar Akhbar el youm press (2003), pp. 324–458.
[16] R.A. Yokel, Blood–brain flux of aluminum ion, manganese, iron ion and other metals suspected to contribute to metal-induced neurodegeneration, J. Alzh. Dis. 10 (2006) 223–253.
[17] A.R. Elmore, Final report on the safety assessment of potassium silicate, sodium metasilicate, and sodium silicate, Int. Toxicol. 24 (Suppl. 1) (2005) 103–117.
[18] L. Paget, L. Barnes, Evaluation of Drug Activities, vol. I, Academic press, 1964.
[19] J. Glowinski, L.L. Iversen, Regional studies of catecholamines in the rat brain, J. Neurochem. 13 (1966) 655–669.
[20] M. Marounek, E. Skřivanová, V. Skřivanová, Selenium content and antioxidant status in tissues of veal calves fed a diet supplemented with selenium yeast, Slovak J. Anim. Sci. 39 (1–2) (2006) 51–54.
[21] R.E. Parker, Introductory Statistics for Biology, second ed., Arnold, London, 1979.
[22] P. Nayak, A.K. Chatterjee, Dietary protein restrication causes modification in aluminum ion-induced alteration in glutamate and GABA system of rat brain, BMC Neurosci. 4 (2003) 1471.
[23] H.M. Wisniewski, J.W. Shek, S. Gruca, J.A. Sturman, Aluminium-induced neurofibrillary changes in axons and dendrites, Acta. Neuropathol. 63 (1984) 190–197.

[24] G.L. Wenk, K.L. Stemmer, Suboptimal dietary zinc intake increases aluminum ion accumulation into the rat brain, Brain Res. 288 (1983) 393–395.
[25] K.S. Rao, Effect of aluminum ion on the brain cells of the rat, Biochem. Int. 28 (1) (1992) 51–56.
[26] B.J. Farnell, D.R. Crapper-McLachlan, K. Bainbridge, U. Deboni, L. Wong, P.L. Wood, Calcium metabolism in aluminum encephalopathy, Exp. Neurol 88 (1985) 68–83.
[27] A.J. Roskams, J.R. Connor, Aluminum ion access to the brain, a role for transferrin and its receptor, Proc. Natl. Acad. Sci. U.S.A. 87 (1990) 9024–9027.
[28] C. Palmer, S. Menzies, R. Roberts, G. Pavlick, J. Konnor, Changes in iron ion histochemistry after hypoxic-ischemic brain energy in the neonatal rat, J. Neurosci. Res. 56 (1999) 60–71.
[29] M.B.H. Youdim, D. Ben-Shachar, P. Riederer, Iron ion in brain function and dysfunction with emphasis on Parkinson's disease, Eur. Neurol. 31 (Suppl. 1) (1991) 34–40.
[30] A. Parrott, A. Morinan, M. Moss, A. Scholey, The brain, neurons and neurotransmitters, in: A. Parrott, A. Morinan, M. Moss, A. Scholey (Eds.), Understanding Drugs and Behavior, John Wiley& Sons, Ltd., Chichester, 2004, pp. 9–24.
[31] S.V. Verstraeten, A.G. Erlejman Zago, P.I. Oteiza, Aluminum ion affects membrane physical properties in human neuroblastoma (IMR-32) cells both before and after differentiation, Arch. Biochem. Biophys. 399 (2002) 167–173.
[32] C.X. Xie, R.A. Yokel, Aluminum ion facilitation of iron ion-mediated lipid peroxidation is dependent on substrate, pH, and aluminum ion and iron ion concentration, Arch. Biochem. Biophys. 327 (2) (1996) 222–226.
[33] R.A. Yokel, The toxicology of aluminum ion in the brain: a review, Neuro Toxicol. 21 (2000) 813–828.
[34] V. Rondeau, A review of epidemiologic studies on aluminum ion and silica in relation to Alzheimer's disease and associated disorders, Rev. Environ. Heal. 17 (2) (2002) 107–121.
[35] M. Horning, V. Krivan, Determination of silicon in biological tissue by electrothermal atomic absorption spectrometry using slurry sampling of original and pre-ashed samples, J. Ann. Atomic Spectro. 12 (1997) 1123–1130.