CEHA Document No: Special Studies; SS-9

Lead Poisoning
The Forgotten Epidemic
Preliminary Study in Qatar

World Health Organization
Regional Office for the Eastern Mediterranean
Regional Centre for Environmental Health Activities
CEHA
Amman, Jordan
1999

This report is based on a special study that was implemented by an expert from the Regional Center for Food Contamination Monitoring, Preventive Medical Services, Ministry of Public Health, Doha, Qatar, and does not necessarily represent the decisions or the stated policy of the World Health Organization.

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CONTENTS

الخلاصة

أجريت هذه الدراسة خلال الفترة من سبتمبر 1995 إلى سبتمبر 1996 م، كجزء من سلسلة من الدراسات التي تهدف إلى التعرف على مدى انتشار الرصاص كملوث في البيئة القطرية، ومدى تعرض الأطفال في قطر إلى أخطار مميتة. شملت الدراسة تحليل 865 عينة لتقدير مستوى الرصاص في مياه الشرب، وبعض الأغذية المتاحة للمستهلك في قطر خصوصا أغذية الأطفال، وكذا مستوى الرصاص في دم بعض الأطفال المحولين لأسباب إكلينيكية. وأظهرت نتائج تحاليل المياه أنه من بين 336 عينة جمعت من الشبكة الرئيسية لمدينة الدوحة وضواحيها، وجدت 39 عينة يرتفع فيها مستوى الرصاص عن الحد الأقصى المقترح من قبل منظمة الصحة العالمية وهو 0.01 مجم/لتر، وبلغ المستوى الأعلى في هذه العينات المخالفة 0،132 مجم/لتر. ومن بين 73 عينة مياه معبأة تمثل 21 علامة تجارية مختلفة، لم تسجل مخالفات إلا في عينتين فقط، حيث وصل المستوى في كل منهما حوالي 0،012 مجم/لتر، أي بزيادة طفيفة عن الحد الأقصى للمستوى المرغوب. وشملت تحاليل المياه أيضا 41 عينة مياه آبار تمثل 12 موقعا جغرافيا مختلفا في قطر، وقد وجد من بينها 6 عينات زاد المستوى فيها عن الحد الأقصى، وكان أعلى مستوى وصلته هذه العينات هو 0،027 مجم/لتر . أما بالنسبة للأغذية، فقد تم تحليل أكثر من 200 عينة أغذية مصنعة، جميعها مستوردة إلى قطر وتنتمي إلى عدد من المجامع الغذائية. وبصورة عامة لم تكن هناك مخالفات خطيرة في مستوى الرصاص في هذه العينات، بما في ذلك تركيبات الرضاعة الصناعية (بدائل لبن الأم)، والمواد التي يكثر استهلاكها من قبل الأطفال (ألبان ومنتجاتها – مشروبات الفاكهة والمشروبات الغازية– منتجات التسلية المصنعة من الذرة والبطاطس)، وباستثناء 3 عينات من الألبان ومنتجاتها وعينة واحدة من حبوب الأرز الجافة، كانت مستويات الرصاص في معظم عينات الأغذية أقل بصورة واضحة من الحدود القصوى المقترحة من قبل اللجنة الدولية لدستور الأغذية. شملت الدراسة أيضا تحليل 200 عينة دم لأطفال (أقل من 15 سنة) محولين من العيادات لأسباب إكلينيكية، ومن بين هؤلاء وجدت ثلاث حالات زاد فيها مستوى الرصاص عن 25 ميكروجرام/100 ملل، وهو الحد الأقصى للمستوى المقبول للرصاص والمعمول به في قطر.

وأعلى مستوى تم رصده كان حوالي 38 ميكروجرام/100 ملل. وتوصي الدراسة بتعديل النظـــام المتبع حاليا للتعامل مع المستويات المرتفعة للرصاص في الدم، واتباع بروتوكـــول جديـــد يتبـــنى حدودا قصوى جديدة هي 10 ميكروجـــرام/100 ملـــل للأطفـــال والســـيدات الحوامـــل و30 ميكروجرام/100 ملل للبالغين. ويوصي البروتوكول بالتدخل الطبي عند تجاوز هـــــذه الحـــدود. وتظهر نتائج هذه الدراسة أن مستوى الرصاص في 19% من الحالات زاد عن الحد الأقصى الجديد المقترح للأطفال (10 ميكروجرام/100 ملل). وبصورة عامة، وبالمقارنة بالنتائج التي سبق جمعها في الثمانينات وبداية التسعينات، تظهر نتائج هذه الدراسة حدوث انخفاضات واضحة في مســـتويات الرصاص في المياه والأغذية ودم الأطفال نتيجة الإجراءات التي تم اتخاذها في دولة قطر للحد مـــن انتشار التلوث بالرصاص. وبالرغم من النجاح الذي تم تحقيقه، توضح الدراسة أن الرصـــاص وان كانت تركيزاته قد انخفضت إلا أنه ما يزال منتشرا كملوث في عناصر البيئة القطرية، وأن نســـبة غير قليلة من الأطفال ما زالت عرضة لتلقي جرعات مرتفعة منه، مما يعرضهم لأخطـــار مميتـــة. ولذلك تؤكد الدراسة على الحاجة إلى إجراء دراسة أوسع، تمكن من جمع المعلومات الإضافية التي تسمح بتقدير متوسط كمية المدخول الكلي اليومي من الرصاص من جميع المصادر الموجـــودة في البيئة القطرية. وكذا رصد الرصاص في الدم في عينة عشوائية من الأطفال على المستوى القومـــي، بالإضافة إلى جميع الحالات المحولة لأسباب إكلينيكية، والسيدات الحوامل والأمهات المرضعـــات، مع اتباع البروتوكول الجديد المقترح.

1. SUMMARY

A total of 450 samples of drinking water were analyzed for measurement of lead levels. From 336 samples collected from various locations in the city of Doha and its suburbs, 39 samples had a lead level exceeding the WHO guideline of 0.01 mg/l. The highest level reached in these violative samples was 0.132 mg/l. Seventy-three samples of bottled water were collected representing 21 brands. Only 2 samples reached a level of 0.012 mg/l, slightly exceeding the WHO guideline value. From a total of 41 samples of underground water representing 12 different geographical locations in Qatar, only 6 samples slightly exceeded the WHO guideline value and the highest level reached was 0.027mg/l. More than 200 samples of processed foodstuffs were analyzed, representing several food groups. Generally, no serious violations in lead levels were found in any samples analyzed. These included infant formulae (17 samples) and commodities widely used by children (26 samples of milk and dairy products, 34 samples of fruit drink products and soft drinks, and 11 samples of potato and corn based snack products). With the exception of 3 samples of milk and dairy products and one sample of rice grains, lead levels were well below the maximum limits recommended by the FAO/WHO Codex Alimentarius Commission. Two hundred blood samples were collected from children (<15 years) referred by pediatric clinics to determine their blood lead levels for diagnostic purposes. Only 3 patients showed values exceeding the level of 25 µg/dl used in Qatar as the maximum limit for normal blood lead. The highest level reached approximately 38 µg/dl and was a single case. Compared to results collected in the eighties and early nineties the present results suggest that there have been significant reductions in lead levels in water, food, and the blood of children. This is due to the measures implemented in the State of Qatar over the last ten years to control the spread of lead contamination. These measures were mainly successful due to the availability of good analytical methods for lead measurement. It is recommended that a wider national survey be conducted to allow better assessment of the average lead intake and blood levels in children, pregnant women and nursing mothers. A new protocol to deal with high blood lead levels in children is proposed to replace the present practice in the State of Qatar. The proposed protocol introduces the new action levels of 10 µg/dl for children and pregnant women and 30 µg/dl for adults replacing the present unified level of 25 µg/dl.

2. OBJECTIVES AND RATIONALE

2.1 Problem Description and Necessity

Monitoring of lead in food and water was started in the State of Qatar by the Regional Center for Food Contamination Monitoring in 1978 (organizations concerned with monitoring lead contamination in Qatar are listed in annexes). Analysis of imported food since then has revealed that some consignments were found to be contaminated with high levels of lead, including foods widely used by children. Several consignments of canned soft drinks and juices were condemned. To find out if there were any cases of lead poisoning among children and occupationally exposed adults, the Center started measuring lead in whole blood in 1982. Analyses carried out since then, on patients referred for laboratory investigation from pediatric clinics showed very high blood lead levels in some children at dangerous levels over 100 µg/dl in some cases. Consequently, the Center became interested in monitoring lead in other environmental matrices to identify sources of lead exposure in the Qatari environment (1).

2.2 Objectives

Due to inadequate funding, the original plan for the study entitled "Food Poisoning in Qatar, the Forgotten Epidemic" will be carried out in several phases depending on the availability of funds. The present study represents only one phase and was conducted as a preliminary survey with the following main objectives:

- to generate sufficient information on lead levels in food and water in order to better assess the dietary intake of lead in Qatar with special emphasis on infants and children. A survey for this purpose was conducted to determine lead levels in some selected foods and drinking water.
- to continue the programme of monitoring blood lead levels in children referred by pediatric clinics for diagnostic investigation.

2.3 Relevance of Proposed Study

This study constitutes a significant part of the effort extended by this Center since 1978, to reduce the dietary intake of lead in Qatar and to minimize the risk of lead poisoning, especially in children. The work on lead poisoning is also one of the priority areas of interest included in the environmental safety programme adopted by this Center.

2.4 Fields of Application for Study Results

The results of this study supplemented by results of earlier studies contributed significantly to the following two important areas:

2.4.1 Food and Water Safety and Regulations

According to the protocol followed in the State of Qatar food and water samples with excessive lead levels were reported to the concerned regulatory agencies responsible for corrective actions.

Water samples were considered excessive when lead levels exceeded 0.05 mg/l. This is the previous WHO guideline value (2) still in-effect in Qatar. Lead levels in water reported in this study, however, have been discussed on the basis of the new WHO guideline level of 0.01 mg/l (3) which will replace the older limits in the near future Corrective action taken included investigation of the violative site to identify and remove the source of lead contamination. Some of the sources more frequently discovered included the piping system, water tanks, and water coolers. Corrective actions are usually considered satisfactory when repeated analyses prove that lead levels in the site no longer exceed the guideline value.

Regarding food, the protocol orders the destruction of any food commodity contaminated with lead levels in excess of the FAO/WHO Codex Alimentarius Commission (CAC) maximum permissible limits (4).

2.4.2 Child Care

The results on blood lead levels in children referred by pediatric clinics for diagnostic laboratory investigation were manipulated according to the following protocol:

- This protocol defines an action level of 25 µg per dl of whole blood. This is the level above which medical intervention is suggested.
- Blood lead levels are reported to the pediatric clinic concerned. Cases with levels higher than 25 µg/dl are dealt with according to the following action schedule:

Level, µg/dl	Action
>25 - <40	- conduct complete medical examination; - investigate environment to eliminate possible sources of exposure, and - follow up on blood lead level.
>40	- conduct complete medical examination; - hospitalize for chelation treatment; - investigate environment to eliminate possible sources of exposure, and - follow up on blood lead level.

- Cases exceeding the action level are also reported to the Department of Preventive Medical Services. With technical support from the Regional Centre for Food Contamination Monitoring, the department undertakes a comprehensive investigation of the patients' environment to identify the possible sources of lead exposure and consequently takes the appropriate corrective measures to eliminate the source.
- Educational information on lead poisoning is circulated to the public through health education programmes carried by various public media (public lectures, TV, radio, and the press).

In addition to food, water, and air as common sources of lead exposure, the following sources of lead were identified as major contributors to high blood lead levels in some children:

- Mothers who are heavy users of lead contaminated cosmetics, especially the traditional eye mascara (Kohl).
- Some brands of water coolers.
- "Pica" in some children.
- Folk medicines and tonics, which were commonly used in the past in Qatar, are sometimes given by mothers to their children to treat illness or to invigorate them. Some of these preparations were found to contain high concentrations of lead and their use is becoming less common due to increased public awareness of the dangers associated with their consumption.

2.5 Review of Literature

A comprehensive review on lead poisoning is not attempted in this report due to the limited nature of this preliminary survey. Emphasis is, however, placed on some facts to highlight the impact of lead on the health of children and help formulate sound recommendations.

2.5.1 Absorption and Distribution of Lead in the Body

Lead, which is a natural constituent of the earth's crust, has become widely spread in the environment as a toxic contaminant by industry and manufacturers. It is particularly detectable in all biological systems and enters the human body through food and water consumed, the air inhaled, and is even absorbed through the skin from cosmetics. In addition to these sources, children can intake appreciable amounts of lead from swallowing, chewing, or licking non-food items such as toys, wall paint, and soil.

Approximately 10% of dietary lead may be absorbed by adults but in infants and young children as much as 50% may be absorbed (5, 6). A deficiency of some nutrients such as iron may increase the absorption of lead. Once absorbed lead is not distributed homogeneously throughout the body. Following a rapid uptake in the blood and soft tissues (liver, lungs, spleen, kidneys, etc.) a slower redistribution of lead to bones and teeth takes place. The major portion of lead in the body is accumulated in the skeleton (about 80-95% in the adult and about 73% in children) with a long half-life of 17-27 years. The turnover rates are much faster for the blood and soft tissue pools with half-life of about 36 and 40 days respectively (6). The non-homogenous distribution pattern of lead in the body is further complicated by many physiological factors making the selection of a simple parameter as an indicator of the body burden of lead a difficult task. However, under conditions of extended exposure, a steady-state distribution of lead between various body organs and systems usually exists to justify the use of blood lead level as a satisfactory indicator (5).

2.5.2 Toxicity

There is no demonstrated biological need for lead in the human body or experimental animals. There is, however, strong evidence that lead adversely affects many systems and biochemical processes in the human body especially those related to haemopoitic, necrologic, and renal functions. Children are more vulnerable to these effects than adults (5, 6, 7, 8, 9, 10).

2.5.2.1 Haemopoitic effects

The effects of lead on the haemopoitic system result in decreased haemoglobin synthesis, and anaemia has been observed at blood lead levels above 40 μg/dl in children and above 50 μg/dl in adults (6).

In lead-induced anaemia, the red blood cells are microcytic and hypochromic, as in iron deficiency, and usually there are increased numbers of reticulocytes with basophilic stippling which results from inhibition of the enzyme pyrimidine-5nucleotidase (8).

Decreased haemoglobin results from impairment of haeme synthesis caused mainly by the ability of lead to inhibit some of the enzymes involved in this process. The main enzymes affected include δ-aminolevulinic acid synthetase, δ-aminolevulinic acid dehydratase (ALA-D), coproporphyrinogen oxidase, and ferrochelatase. These enzymatic changes occur at blood lead levels much lower than the levels associated with the appearance of anemia. The activity of δ-ALA-D is especially sensitive to lead and may be inhibited at blood lead levels as low as 5 μg/dl in children (6). The enzymatic inhibition leads to elevated levels of some metabolites in this pathway, in circulating blood and to an increase in their urinary excretion. The changes in enzyme activities particularly δ-ALA-D in peripheral blood and excretion of δ-aminolevulinic acid in urine correlate closely with blood lead levels and can, therefore, be used as indicators of lead exposure (8). In addition to impairment of haeme synthesis, lead has also been reported to induce the acceleration of erythrocyte destruction (6,8).

2.5.2.2 Neurologic effects

Lead may effect the brain and several central and peripheral neurofunctions. Evidence for the effect of lead on the nervous system can be clearly demonstrated from the electrophysiological measurement of nerve conduction velocities. Aberrant electroencephalograph readings in children were significantly correlated with blood lead levels down to 15 μg/dl (6). Significant reductions in maximal motor nerve conduction velocity (MNCV) have been observed in children (5-9 years) living near a smelter, with a threshold occurring at blood lead level around 20 µg/dl; a 2% decrease in the MNCV was seen for every 10 µg/dl increase in blood lead level (6, 11). Clinically lead encephalopathy may occur in children with high exposure to lead and at blood lead levels above 80 µg/dl (8). Symptoms begin with lethargy, vomiting, irritability, and dizziness, and may progress to ataxia. coma, convulsion, and death may be attributed to severe edema resulting from increased permeability of brain capillaries leading to leakage of fluids and red blood cells (5, 8).

The most significant effect of lead exposure in children is reduced cognitive development and intellectual performance. Many studies have been conducted during the last 20 years in several countries including the U.S.A, the U.K, and Australia on the relationship between the body burden of lead and neurobehavioral development in children. Dentine and blood lead levels have been used as indicators of the body lead burden. Inconsistencies between these studies were attributed to a multitude of variables including several socioeconomic factors. Nevertheless it may be broadly generalized that in children with blood lead levels below 25 µg/dl there is a loss of 1-3 points in the intelligence quotient (IQ) for each 10, µg/dl increment in blood lead level and there is some evidence of an association between lead exposure and cognitive deficits even in the 7 - 8 µg/dl range (12). Consequently some countries have recently reduced their action levels from 25 µg/dl to much lower levels. In the U.S.A the current levels of concern are 10 µg/dl for infants, young children and pregnant women and 30 µg/dl for adults (9, 10, 13, 14). Lead induced behavioral toxicity may be due to biochemical and neurochemical changes. Protein kinases present in nerve terminals involved in modulating the release of neurotransmitters are affected by lead. Animal studies suggest that lead affects all neurotransmitter systems and may impair their functions by inducing biochemical changes (5, 6, 7, 8). Some studies suggested that lead can cause changes in the N-methyl-D-aspartate receptor complex implicated in the learning and memory processes (5).

Lead induced neurological toxicity may be also attributed to impairment of respiration in brain mitochondria as shown by some in vitro studies using brains of lead-exposed rats.

2.5.2.3 Renal effects

Lead can induce several significant toxicological effects on the kidneys. Studies in rats suggest that there is a threshold for lead nephropathy with a blood lead level of about 45 µg/dl (8). The major toxicological effects include renal tubular dysfunction which is reversible and occurs mostly in children acutely exposed to lead and chronic interstitial nephropathy which is irreversible and which is characterized by vascular sclerosis, tubular cell atrophy, interstitial fibrosis, and glomerular sclerosis (8).

2.5.2.4 Other effects

There are several other effects thought to be associated with lead exposure. Following is a brief account of effects for which some evidence is already available from epidemiological and experimental animal studies:

- Effect on blood pressure: Chronic low-level exposure to lead produced elevation in blood pressure in rats (5). Epidemiological studies in the U.S.A. and U.K. provided evidence demonstrating small but a statistically significant association between blood lead level and increased blood pressure in adult men; the strongest association was for males aged 40 to 59 and for systolic somewhat more so than for diastolic pressure (8).
- Effects on the reproductive system: Severe lead toxicity can cause sterility, abortion and neonatal mortality and morbidity. Studies have demonstrated gametotoxic effects in both male and female animals (8). Gonadal dysfunction in men, including depressed sperm counts, has been associated with blood lead levels of 40 - 50 μg/dl (6). Epidemiological studies have shown that the risk of preterm delivery was more than four times higher among pregnant women with blood lead levels above 14 μg/dl than in those with 8 μg/dl or less (6).
- Immunological effects: Lead induced immunosuppression occurs at low doses in experimental animals in which there is no apparent evidence of toxicity (8). Lead impairs antibody production in animals and generally decreases immunoglobin plaque-forming cells (5).
- Carcinogenecity: There is some evidence for lead-induced carcinogenecity in animals but available evidence in humans is not adequate. Lead induction of renal adenocarcinoma in rats and mice is dose related and has not been reported at levels below that which produce nephrotoxicity (8, 15).

2.5.3 Dietary Intake of Lead

After assessing the health risks of lead to infants and children the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established in 1986 a new Provisional Tolerable Weekly Intake (PTWI) of 25 μg/kg of body weight for this population group. This includes lead from all sources (12). Relative contributions of various sources of lead to the total intake of this toxic metal vary from one country to another and even between communities within the same country depending on many factors including the level and type of industrialization exploiting lead and lead containing materials, food and water consumption patterns, in addition to other economic and social factors. Under most conditions worldwide food probably represents the major source of lead exposure accounting for more than 80% of the total intake in many countries. However, the proportion of dietary contribution has been continuously declining especially in the developed countries as a result of continued efforts started during the 1970's to minimize dietary intake of lead. In the U.S. the average daily dietary intake of the adolescent male

(14 - 16 years) declined from about 38 µg in 1982 - 1984 to about 2 µg in 1986 - 1988, then to only about 3.2 µg in the period 1990- 1991. Great reductions have also been achieved for infants and young children from about 34 and 44 µg to less than 2 µg over the same period (13, 14, 16). Reductions in dietary intake of lead have also been reported in other countries. In Denmark, the average dietary intake of the adult decreased from 42 µg during 1983 - 1987 to 27 µg during 1988 - 1992 (17). The Australian Market Basket Survey of 1992 (18) reported that the highest dietary intake of lead per unit body weight was in young children of 2 years in comparison with other age groups included in the survey. The average intake of these children was estimated in this survey to be nearly 12 µg/day and for adult males about 46 µg/day. Comparison with an earlier survey conducted in 1987 showed that the average dietary intake of lead decreased by more than 50% during this period. Reductions in lead intake were also reported in the Netherlands. Total diet studies (19) showed that mean intake of lead in 16 - 19 year old boys dropped from 32 µg/day in 1984/86 to 23 µg/day in 1988/89.

Total diet studies have not yet been conducted in the State of Qatar but reductions in dietary intake of lead may be inferred from the remarkable decline in lead levels in food and water as demonstrated by the monitoring surveys conducted since 1978. Some of the major sources of lead exposure in Qatar have been reported (1). High levels of lead were detected during the late 1970's and during the 1980's in some shipments of imported food especially soft drinks and fruit juices canned in lead-soldered containers. Lead concentrations reached more than 0.6 ppm in some brands of soft drinks and more than 2 ppm in some brands of fruit juices exceeding by far the FAO/WHO Codex Alimentarius Commission (CAC) maximum limits of 0.2 and 0.3 ppm, respectively. Consequent to the strict enforcement of the CAC's limits for food and the WHO guideline value (0.05 mg/l) for water reduction trends have been observed in lead levels in food and water over the last 15 years.

The Qatari surveys also included since l982 monitoring of lead levels in the blood of children referred for clinical reasons and also in some occupationally exposed workers. Values above the action level of 25 µg/dl were frequently detected in children especially in the younger age group of up to 5 years. Levels above 50 µg/dl were reported for many cases in children and occupationally exposed workers (1).

3. EXPERIMENTAL DESIGN AND METHODOLOGY

3.1 Summary of Methodology

Lead level in water was determined by Differential Pulse Anodic Stripping Voltametry (DPASV) and in food and blood using Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS).

3.2 Samples

Water: A total of 450 samples were collected to represent: various locations along the main water supply network in Doha (336 samples), locally produced and imported bottled water (73 samples), and underground water from 12 different geographical locations in Qatar (41 samples).

Food: A total of 204 samples of processed foods were randomly collected from imported consignments at various points of entry to Qatar as well as from the local market. All commodities sampled were manufactured outside of Qatar. No metal cans included in this study used lead soldering, and ten samples of fresh fish, representing seven of the most popular species of Gulf fish and one sample of shrimp were collected from the Central Fish Market. Only the edible portions were analyzed.

Blood: A total of 200 specimens were collected from children (<15 years) referred to this Center from pediatric clinics for diagnostic investigation. Analysis was conducted on whole blood.

3.3 Methods of Analysis

3.3.1 Water

Lead was determined in water samples by Differential Pulse Anodic Stripping Voltametry (DPASV) using an EG & G Polarograph, Model 384 equipped with a hanging mercury drop electrode (HMDE). The supporting electrolyte used was the acetate buffer at pH 4.5 (20, 21).

Sample processing: Immediately after collection, water samples were preserved by adding concentrated HNO3 (Aristar grade) at the rate of l ml/litre of sample and mixing well a 5 ml pipette of sample into the cell and adding 5 ml of the acetate buffer solution.

Instrumental parameters

Working electrode	:	HMDE, medium size drop.
Mode	:	DPS
Modulation amplitude	:	25mV
Purge time	:	60 sec .
Initial/deposition potential	:	- 0.8 V vs Ag/AgCl.
Measurement/drop time	:	1.0 sec.
Deposition time	:	180 sec (stirring), 10 sec (equilibration)
Scan direction	:	+ ve.

3.3.2 Food

After proper sample processing lead was measured by GFAAS using a Varian Spectra A-800 with Zeeman background correction. Instrumental parameters were set according to manufacturer specification (22).

Sample processing

Oils: Ash was obtained from a 2 g sample at 450°C. Digest ash mixed with 5 ml of 2N HNO3 was boiled for 1 minute, cooled and made up to 10 ml, then diluted to 100 ml with $(NH_4)H_2PO_4$ (5 mg/ml).

Carbonated beverages: These were de-carbonated by stirring for about 5 minutes. using a magnetic stirrer, then 10ml was transferred to a volumetric flask and diluted to 100 ml with $(NH_4)H_2PO_4$ (5mg/ml).

Other food samples: About 0.3 g of sample was digested using 4 ml concentration of HNO_3 (Aristar grade) and 1 ml of 30% H_2O_2 (Analar grade) in a pressurized condition using a microwave digester (Milestone 1200 MEGA). The digest was cooled and made up to 10 ml volume. 1 ml of this solution was further diluted to 10 ml with $(NH_4)H_2PO_4$ (5 mg/ml).

3.3.3 Blood

Method: Lead was measured in whole blood by Graphite Furnace Atomic Absorption Spectrophotometer according to Flainik and Shrader (23).

Reagents and standards

- Triton X-100;
- 20% $(NH_4)H_2PO_4$ (Analar grade);
- Concentrated HNO_3 (Aristar grade);
- Working modifier To 400 ml deionized water added to 2.5 ml of a10% Triton X-100 solution, 5.0 ml of 20% $(NH_4)H_2PO_4$ and a 1.0 ml concentration of HNO_3, making up to 500 ml (stable for 3 months);
- Stock Pb standard 1000 µg/ml (Spectrosol grade);
- Intermediate Pb standard A 10 µg/ml (diluted 1 ml stock to 100 ml with deionized water);
- Intermediate Pb standard B 1.0 µg/ml (diluted 10 ml of intermediate standard A to 100 ml with deionized water);
- Working Pb standard 0.05 µg/ml (to 5.0 ml of intermediate standard B added to 5.0 ml of deionized water in a 100 ml standard flask, made up to 100 ml with a working modifier solution).

Sample preparation: Dilute 1.0 ml of whole blood to 10 ml with working modifier.

Instrument: Varian Spectra A-800 with Zeeman background correction.

3.4 Analytical Quality Assurance

The following certified reference materials obtained from the European Community Bureau of Reference BCR (24) were used in the analysis for quality assurance: BCR Certified Reference Material No.62 (Olive Leaves), and BCR Certified Reference Material No.194 (Lyophilized Blood)

3.5 Statistical Analysis

Some of the data were not completely suitable for a typical analysis of variance and thus were presented as ranges. Where appropriate the average, the median, and the standard deviation were calculated using Microsoft Excel running on a Pentium based PC (HP Series 3).

4. Results and Discussions

4.1 Water

Lead levels of water samples analyzed are presented in **Annex (1)**. From a total of 336 samples collected from the main municipal supply network in the city of Doha and its suburbs 39 samples exceeded the WHO guideline value of 0.01mg/l for lead. The levels in some samples reached more than 10 times this guideline value. Included in these municipal supply samples were 66 samples collected from water coolers in public schools. Nine of these cooler samples (about 14%) contained lead levels exceeding the WHO guideline value. The highest level reached in these samples was 0.074 mg/l

Comparison of these results with earlier results collected during the last 15 years shows significant reductions in lead levels in the municipal main network. During the period of 1987-1989 high levels were detected in several locations of the network exceeding sometimes 0.3 mg/l. Several of these serious violations were detected in some schools where some brands of water coolers were discovered leaching high levels of lead into drinking water. The reduction in lead levels observed in recent years came as a result of some corrective actions taken to improve the quality of the municipal water supply. Mention should be made here of some of these actions:

- Modification of the composition of the water which is produced mainly by desalinating Gulf water to reduce its corrosivity.
- Replacement of the main network with better quality materials and changing most domestic metal piping systems to copper.

- Removal of all water coolers that were discovered leaching lead into drinking water. Only certain brands were found violative and were immediately replaced by better quality coolers.

Seventy-three samples of bottled water representing 21 different brands were analyzed and only two samples were slightly above the guideline value of 0.01mg/l. The highest lead level was only 0.012 mg/l.

Underground water represents the major source for human consumption outside the city limits of Doha and other neighbouring cities. Forty-one samples of underground water representing 12 different geographical locations were analyzed and the lead levels in 6 samples exceeded the guideline value with the highest level reaching only 0.027 mg/l.

These results suggest that among all water sources used for human consumption the main municipal supply network represents a major source of lead exposure in Qatar. It should be pointed out, however, that the State of Qatar is still enforcing the previous WHO guideline value of 0.05mg/l. Any site exceeding this level is considered violative and immediate action is taken by the concerned authorities to correct the violation. As the levels have been declining over the last 10 years, Qatar will soon be ready to introduce the new WHO guideline value of 0.01 mg/l into its water quality programme.

4.2 Food

More than 200 samples of processed foodstuffs have been analyzed representing several food groups with special emphasis on infant formulae and commodities widely used by children. Results of lead levels in these samples are presented in **Annex (2)**. Fish constitutes a major portion of the Qatari diet. Results of the analysis of 11 samples of some of the popular species in the Gulf are also shown in **Annex (2)**.

Due to the limited nature of this study the number of samples analyzed was not sufficient to allow adequate representation of all major brands of foods available for consumption in Qatar. Another survey is needed to bridge this gap. The present results, however, provide an indicator for the general trends of lead levels since the 1970's and 1980's.

Generally no serious violations in lead levels were found in most samples of processed food and fresh fish analyzed in this study on the basis of the maximum limits acceptable internationally (CAC). From the 204 samples of processed food analyzed only four were found with lead levels exceeding the acceptable limits:

- One sample of pasteurized whole liquid milk had a lead level of 0.049 mg/l and a sample of yoghurt carrying the same brand name had 0.048 mg/kg. These two products along with several other dairy products of the same brand name are imported into Qatar from a neighbouring country and technologically considered the best quality milk and milk products available in the Qatari market. These two levels of lead do not seem to be high enough to cause any immediate concern but they express the need for wider continuous coverage of milk and dairy products to assure compliance with the targeted limit of 0.02 mg/l for liquid milk.

- One sample of a nutritional milk-based supplement in powder form, manufactured in Holland, had a lead level of 0.3174mg/kg. According to the label the product contained basic food constituents, vitamins, and minerals and claimed to have been formulated for the continued health and well-being of infants, children and adults. The label in another place, however, indicated "Not for Infants". This lead level is considered high in comparison with the limit of 0.2 mg/kg widely used internationally for powdered milk and children's foods. This limit, however, is inappropriate to apply to this product as it is used with powdered milk on the basis that milk powders are diluted by seven to ten times to prepare the product for consumption. It can then be expected to contain about 0.02 - 0.03 mg/l which is equivalent to the limit widely used for liquid milk. The label of this nutritional supplement recommended that it be prepared with water at the ratio of 1 to 1. This means that the lead level in the prepared beverage is expected to be about half of the level of the original powdered form or about 0.15 mg/l which is remarkably higher than the limit for liquid milk.
- One sample of basmati rice imported from India had a lead level of 3.4722 mg/kg. This level is too high compared to another sample of basmati rice imported from Pakistan with a lead level of <0.0001 mg/kg. The limit recommended for lead in cereal grains is 0.1 mg/kg. Rice is widely used in the Gulf region and represents one of the main important daily dishes of the average diet. There are many varieties of rice imported into Qatar from several countries and all should be subject to continuous monitoring for lead to avoid imports of contaminated brands.

In spite of these four cases of violations, lead levels reported in this study are generally much lower than those previously reported during the 1970's and 1980's. High levels of lead were widely detected in processed foods imported into Qatar during that period, especially canned soft drinks and acidic products. The following are examples of those earlier levels:

- In 1979 many samples of fruit juices had lead levels exceeding the limit of 0.3 mg/l; levels as high as 2.2 mg/l were detected in a brand of apple juice.
- In 1980 several violations were reported in some brands of soft drinks. Lead levels were frequently above the limit of 0.2 mg/l reaching more than 0.6 mg/l in several samples and in one case a small piece of lead metal was found free in the contents of one can.

A major contributing source to the high lead levels in food and beverages during those earlier years was the wide use of lead soldering in the canning industry. Tin soldering and the use of new materials such as aluminium, glass, plastic and paper in the manufacture of containers has gradually replaced the lead soldered can over the last ten years.

Results of fresh fish analysis showed that lead levels in all 11 samples were well below the limit of 0.5 mg/kg acceptable internationally. The highest level reached only 0.1152 mg/kg. Previous monitoring surveys carried out since 1985 by this Center on contaminants of the marine environment in the Qatari waters of the Gulf showed wide intra-and inter-species variations in the levels of mercury, lead and other heavy metals in edible Gulf fish and crustaceans (unpublished). High levels of mercury were sometimes detected especially in carnivorous fish but lead was usually within the limit. The highest lead level in these surveys was 1.13 mg/kg detected in 1995 in one sample of "Indian Flathead", a species not widely consumed in Qatar. The most popular species, Greasy Grouper (Hamour), had lead levels ranging between 0.02 and 0.09 mg/kg for the two samples analyzed in this study. These levels are much below the limit of 0.5 mg/kg but since fish is consumed in large amounts in the Gulf region, the contribution of fish to the total dietary intake of lead may be significant. Therefore, accurate assessment of the average dietary intake of lead in Qatar requires continuous monitoring of lead in the popular species of fish and crustaceans available to the consumer.

4.3 Blood

Results of the analysis of blood are presented in **Annex (3)**. Only three patients had values exceeding the action level of 25 µg/dl currently followed in Qatar. The maximum level reached was about 38 µg/dl and was reported in a single case. In comparison with earlier results collected during the three-year period of 1992 - 1994 (**Annex 4**) the present levels are remarkably lower. Breakdowns of blood lead levels according to age (**Annex 4**) show that the majority of the high levels were detected in the youngest age group of up to 5 years.

In view of the fact that several reports have indicated that some of the adverse effects of lead in children, especially those related to cognitive development and intellectual performance may be induced at blood lead levels below 10 µg/dl (9, 12), the call for lowering the action level to 10 µg/dl may be justified. In the present study there were 38 patients (representing 19 % of all 200 cases studied) discovered with blood lead levels exceeding 10 µg/dl. The proportion of cases in earlier surveys exceeding this level or the current action level of 25 µg/dl were much higher as shown in **Annex (5)**. The decline in blood lead levels reported in this study as compared with earlier surveys may be attributed to several factors including:

- Reductions in dietary intake of lead as a result to decreased lead levels in food and water.

- Increased awareness of the consumer in response to health education programmes dealing with the problem of lead poisoning and sources of lead exposure in Qatar.
- Increased awareness among all personnel of the medical services concerned, both preventive and curative, of the presence of dangerous blood lead levels in some children in Qatar. This awareness led to more accurate diagnosis and consequently to more effective treatment and preventive measures.

It should be pointed out that all results of blood analysis in this study and in earlier surveys represented biased samples collected only from patients referred by the pediatric clinics for diagnostic investigations. These results do not, therefore, represent the national blood lead levels for children in Qatar. However, they were found useful, clinically as well as preventively, as they provided the following two sets of information and consequent actions:

- Detection of some of the highest blood lead levels expected in children since the blood specimens analyzed were collected from patients who were suspected of having high blood lead levels and were referred by clinics for diagnostic investigation. Many of these patients were found to have low levels and underwent further investigation for proper diagnosis. Patients with high lead levels, on the other hand, received effective treatment according to the lead poisoning protocol followed in Qatar.
- Identification by survey, of patient environments discovered sources of lead exposure resulting in high blood lead levels. Consequently, measures were taken to eliminate sources identified.

These results along with results of previous surveys (1) support this Center's call for an adequately supported national survey of blood lead levels in children and pregnant women and of sources of lead exposure in the environment.

5. CONCLUSIONS AND RECOMMENDATIONS

The results collected in this survey show an impressive decline in levels of lead in some of the major food commodities (especially infant and children's foods) available to consumers in Qatar in comparison with levels detected in the late 1970's and the 1980's. A decline has also been noted in lead levels in drinking water but some violations were recorded from sites along the main municipal supply network where lead levels exceeded the WHO guideline value of 0.01 mg/l. The results on blood lead levels showed similar trends in comparison with previous analysis but the survey revealed en appreciable portion (19%) of the investigated 200 cases with blood lead levels exceeding 10 µg/dl.

The result of this limited survey acknowledges the good efforts of contamination monitoring organizations in Qatar in dealing with the lead problem. Greater efforts are, however, still needed to provide better protection to consumers, especially children against the dangers of lead poisoning. To achieve this goal it is recommended that a project on "Lead Poisoning" be established in the Ministry of Health with adequate financial support to undertake the following tasks:

- Conduct a wider study to assess all sources of lead exposure in Qatar including air and estimate the average lead intake of various sensitive age groups.
- Carry out a survey to measure blood lead levels in random samples of preschool nd primary school children.
- Strengthen and support to the current programme for blood lead measurement of all patients referred by pediatric clinics and by the Occupational Health Section and to change the blood lead action level to 10 µg/dl for infants, young children and pregnant women and to 30 µg/dl for adults. The following medical intervention schedule is proposed for children:

Level, µg/dl	Action
>10 - <25	- investigate environment to eliminate possible sources of exposure, and - follow up on blood lead level.
25 - <40	-hospitalize to protect from possible sources of exposure; - conduct complete medical examination; - consider treatment; - investigate environment to eliminate possible sources of exposure, and - follow up on blood lead level.
>40	- hospitalize; - conduct complete medical examination; - apply chelation treatment; - investigate environment to eliminate possible sources of exposure, and - follow up on blood lead level.

- Organize a programme to monitor the blood levels of pregnant women and nursing mothers.
- Carry out investigations required to identify sources of lead exposure in the environment of all individuals discovered with high blood lead levels.

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Annex (1)
Lead Levels in Water Samples

	Total number of samples	450
1.	Doha Main Network Number of samples (Taken from various locations in the city of Doha and suburbs)	336
	Range of lead level	<0.0001 - 0.1320 mg/l
	Average ± SD	0.0046 ± 0.0110 mg/l
	Median	0.0014 mg/l
	Samples exceeding WHO Guideline Level of 0.01 mg/l	39
2.	Bottled Water	
	Number of samples	73
	Number of brands	21
	Range of lead level	<0.0007 - 0.0120 mg/l
	Average ± SD	0.0028 ± 0.0026 mg/l
	Median Samples exceeding WHO Guideline Level of 0.01 mg/l	0.0020 mg/l 2
3.	Underground Water	
	Number of samples	41
	Number of locations	12
	Range of lead level	<0.0001 - 0.0270 mg/l
	Average ± SD	0.0040 ± 0.0064 mg/l
	Median Samples exceeding WHO Guideline Level of 0.01 mg/l	0.0019 mg/l 6

Annex (2)
Lead Levels in Food Samples

Total number of samples — 215

No	Nature of Sample	No. of Samples Analyzed	Pb Level Range mg/kg or mg/l
1.	Infant Formulae	17	<0.0001 - 0.0432
2.	Pasteurized Milk and Fermented Products	4	0.0089 - 0.049
3.	Flavoured Milk Drinks	3	0.0001 - 0.0019
4.	Full Cream Milk Powder	6	<0.0001 - 0.0254
5.	Evaporated Milk (can)	7	0.0035 - 0.0333
6.	Cheese	6	<0.0001 - 0.3220
7.	Nutritional Supplement and Food Drinks Powders	6	<0.0001 - 0.3174
8.	Canned Fruit Products	5	<0.0001 - 0.1049
9.	Fruit Drink Products (ready-to-drink)		
	Tin can	10	<0.0001 - 0.1716
	Al foil pouch	9	<0.0001 - 0.0537
10.	Carbonated Soft Drinks		
	Al Cans	12	<0.0001 - 0.0053
	Glass Bottles	12	<0.0001 - 0.0266
11.	Cereal Products:		
	Wheat Flour	2	<0.0001
	Rice	2	<0.0001 - 3.4722
	Semolina	1	<0.0001
	Breakfast Cereals	7	<0.0001 - 0.0173
	Biscuits	5	<0.0001 - 0.0968
12.	Edible Vegetable Oils:		
	Plastic Cans	10	<0.0001 - 0.0811
	Metal Cans	2	0.0082 - 0.0227
13.	Canned Meat Products	4	<0.0001 - 0.1748
14.	Canned Fish Products	15	<0.0001 - 0.2900
15.	Candies	10	<0.0001 - 0.1842
16.	Marshmallows	1	<0.0001
17.	Custard Powder	4	0.0096 - 0.1004
18.	Honey	7	<0.0001 - 0.1943
19.	Edible Ices:		
	Icecream	3	<0.0001
	Lollipops	1	<0.0001
20.	Cane Molasses	1	0.12
21.	Cane Sugar	2	<0.0001
22.	Fruit Preservers:		
	Can	4	<0.0001
	Bottles	3	0.0028 - 0.0377
23.	Snacks (Potato and Corn Based)	11	<0.0001 - 0.0169
24.	Canned Mushrooms	1	<0.0001
25.	Mayonnaise	1	<0.0001
26.	Spices	10	0.2484 - 1.3867
27.	Fresh Fish	11	<0.0001 - 0.1152

Annex (3)

Blood Lead Levels of Children Referred by the Pediatric Clinics During the Period of This Study 1995/1996

Total number of samples	:	--	200
Range of Pb level, µg/dl	**:**	**0.50 - 37.50 µg/dl**	
Average ± SD	:	6.66 ± 4.93 µg/dl	
Number of samples with 10 µg/dl	:	--	38
Number of samples with > 25 µg/dl	:	--	3

Annex (4)

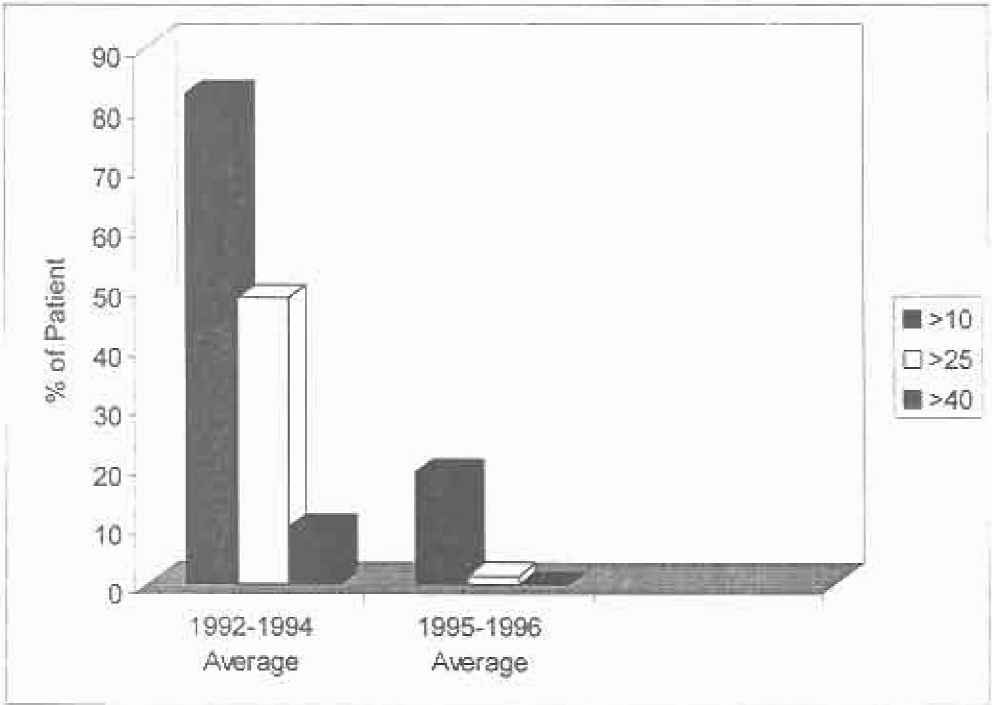
Breakdown of Blood Lead Levels of Children According to Age

Comparison Between Earlier Surveys (1992-1994) and the Present Study (1995 - 1996)

Year	Total No. of Samples	Blood Lead Levels, µg/dl											
		Up to 25			>25 - 40			>40 - 50			>50		
		Age, years											
		Up to 5	>5-10	>10-15	Up to 5	>5-10	>10-15	Up to 5	>5-10	>10-15	Up to 5	>5-10	>10-15
1992	152	64	5	1	45	4	3	11	2	...	14	3	...
1993	359	159	34	5	93	9	1	29	1	...	28	...	...
1994	354	128	45	6	81	18	7	36	4	1	27	1	...
95/96	200	147	42	8	3	...	...	...	...	...	...	...	...

Annex (5)

Blood Lead Levels, Percentage of Patients with Levels of >10, >25, or >40 μg/dl Comparison between the Average for the Three year period 1992-1994 and the Present Study 1995-1996



Annex (6)

ORGANIZATIONS CONCERNED WITH MONITORING LEAD CONTAMINATION IN QATAR

I. Ministry of Public Health

A. Preventive Medical Services

1. The Regional Centre for Food Contamination Monitoring
2. Food Inspection, Port Health Section
3. Environmental Health Section
4. Occupational Health Section

B. Hamad Medical Corporation

Department of Pediatrics, Hamad General Hospital

II. Ministry of Municipal Affairs and Agriculture

1. Food Control Section
2. Environment Department