Child Labour and Health Hazards: Chemical Exposure and Occupational Injuries in Nicaraguan Children Working in a Waste Disposal Site

Steven Cuadra

Division of Occupational and Environmental Medicine and Psychiatric Epidemiology, Department of Laboratory Medicine, Lund University, Sweden

Licentiate thesis

Faculty of Medicine, Lund University

Lund 2005
A mi madre Gladys,
la mayor prueba del amor de Dios en mi vida

A Nestor,
Mi hermano, mi compañero, mi mejor amigo
Y Sandino no era inteligente ni era culto pero salió inteligente de la montaña. “En la montaña todo enseña” decía Sandino (Soñando con las Segovias llenas de escuelas)

(Ernesto Cardenal)

And though I have the gift of prophecy, and understand all mysteries, and all knowledge; and though I have all faith, so that I could remove mountains, and have not charity, I am nothing. (1 Corinthians 13:2)

“Y si tengo el don de la palabra y estoy enterado de todos los misterios, y de todo el conocimiento, y si tengo la fe como para trasladar montañas, pero no tengo amor, nada soy” (1 Corintios 13:2)
Contents

Contents.................................................................................................................. 5
Abbreviations.......................................................................................................... 7
List of papers ......................................................................................................... 9
Introduction ........................................................................................................... 10
  Child labour in figures ....................................................................................... 10
  Working at waste disposal sites.......................................................................... 10
  Health hazards in child workers at waste disposal site...................................... 11
    Chemical exposures .......................................................................................... 11
    Heavy metals ..................................................................................................... 12
    Persistent organochlorine pollutants (POPs) .................................................. 13
    Polybrominated diphenyl ethers (PBDEs) ....................................................... 16
    Injuries at the work place.................................................................................. 17
Aims of the thesis .................................................................................................. 18
Area description .................................................................................................... 19
  Managua waste disposal site .............................................................................. 19
Material and methods ........................................................................................... 20
  Study populations ............................................................................................. 20
  Non-participants ................................................................................................ 21
  Data collection .................................................................................................... 21
    Interviews ......................................................................................................... 21
      Background questionnaire (Paper I, II, III and IV) ..................................... 21
      Injury questionnaire (Paper IV) .................................................................... 22
    Blood Sampling ................................................................................................. 22
    Soil sampling .................................................................................................... 22
  Chemical analysis ............................................................................................... 23
    Determination of metals (Pb, Hg, Cd, Se and Fe) in blood ................................ 23
    Determination of metals in soil ........................................................................ 23
    Determination of persistent organochlorine pollutants and PBDEs in serum . 23
  Data analysis ...................................................................................................... 26
    Paper I .............................................................................................................. 26
    Paper II and III ................................................................................................. 26
    Paper IV ............................................................................................................ 26
      Injury risk estimation ...................................................................................... 26
        Classification of work related injuries (WRIs) ............................................. 27
Ethical approval .................................................................................................... 27
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-OH-CB</td>
<td>Hydroxylated metabolites of polychlorinated biphenyls</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>B-Cd</td>
<td>Blood Cadmium</td>
</tr>
<tr>
<td>BDE-100</td>
<td>2,2',4,4',6-pentaBDE</td>
</tr>
<tr>
<td>BDE-153</td>
<td>2,2',4,4',5,5'-hexaBDE</td>
</tr>
<tr>
<td>BDE-183</td>
<td>2,2',3,4,4',5,6-heptaBDE</td>
</tr>
<tr>
<td>BDE-203</td>
<td>2,2',3,4,4',5,5',6-octaBDE</td>
</tr>
<tr>
<td>BDE-209</td>
<td>2,2',3,3',4,4',5,5',6,6'-decaBDE</td>
</tr>
<tr>
<td>BDE-47</td>
<td>2,2',4,4'-tetraBDE</td>
</tr>
<tr>
<td>BDE-99</td>
<td>2,2',4,4',5-pentaBDE</td>
</tr>
<tr>
<td>B-Fe</td>
<td>Blood iron</td>
</tr>
<tr>
<td>B-Hg</td>
<td>Blood mercury</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>B-Pb</td>
<td>Blood lead</td>
</tr>
<tr>
<td>B-Se</td>
<td>Blood selenium</td>
</tr>
<tr>
<td>CB 153</td>
<td>2,2',4,4',5,5',hexachlorobiphenyl</td>
</tr>
<tr>
<td>Cd</td>
<td>Cadmium</td>
</tr>
<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention</td>
</tr>
<tr>
<td>DDD</td>
<td>Dichloro-diphenyl-dichloro-ethane</td>
</tr>
<tr>
<td>DDE</td>
<td>Dichloro-diphenyl-dichloro-ethylene</td>
</tr>
<tr>
<td>DDT</td>
<td>Dichloro-diphenyl-trichloro-ethylene</td>
</tr>
<tr>
<td>ECNI</td>
<td>Electron capture chemical ionization</td>
</tr>
<tr>
<td>ENTIA</td>
<td>Child and Adolescents Labour Survey</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>f.w.</td>
<td>Fresh weight</td>
</tr>
<tr>
<td>Fe</td>
<td>Iron</td>
</tr>
<tr>
<td>g</td>
<td>Gram</td>
</tr>
<tr>
<td>GC-MS</td>
<td>Gas Chromatography-Mass Spectrometry</td>
</tr>
<tr>
<td>HCB</td>
<td>Hexachlorobenzene</td>
</tr>
<tr>
<td>HCH</td>
<td>Hexachlorocyclohexane</td>
</tr>
<tr>
<td>Hg</td>
<td>Mercury</td>
</tr>
<tr>
<td>HPCs</td>
<td>Halogenated phenolic compounds</td>
</tr>
<tr>
<td>IC</td>
<td>Interval confidence</td>
</tr>
<tr>
<td>ICP-OES</td>
<td>Inductively Coupled Plasma Optical Emission Spectroscopy</td>
</tr>
<tr>
<td>ILO</td>
<td>The International Labour Office</td>
</tr>
</tbody>
</table>
IPEC International Programme on the Elimination of Child Labour
IR Incidence rate
kg Kilogram
l Liter
l.w. Lipid weight
LOD Limit of detection
LOQ Limit of quantification
mg Milligram
ng Nanogram
NGO Non-governmental organization
Non-WRI Non-Work related injury
OH-PCB Hydroxylated PCB
OR Odds ratio
Pb Lead
pbb part per billion
PBDE Polybrominated diphenyl ethers
PCB Polychlorinated biphenyls
PCP Pentachlorophenol
PMIA Multidisciplinary Environmental Research Program
POP Persistent organochlorine pollutant
ppm part pert million
RR Rate ratio
RFD Reference Dose
Se Selenium
µg Microgram
UK United Kingdom
UNAN National Autonomous University of Nicaragua
USA United States of America
WHO World Health Organization
WRI Work related injury
List of papers

This thesis is based on the following four papers, which are included at the end and referred to in the text according to their roman numerals.

I. Cuadra S N, Karlsson J-E, Lundh T, Jakobsson K. Heavy metal exposure in children working at a waste disposal site and in referent children from Managua, Nicaragua. (In manuscript)

II. Cuadra S N, Linderholm L, Athanasiadou M, Jakobsson K. Persistent organochlorine pollutants in children working at a waste disposal site, and in young females with high fish consumption in Managua, Nicaragua. Ambio 0, 0-0.


IV. Cuadra S N, Axmon A, Hernández D, Jiménez M, Albin M, Jakobsson K. Work related injuries in children working at a waste disposal site in Nicaragua, and in referents. (Submitted)
Introduction

Child labour remains a widespread problem in the world today (1,2). Unacceptable forms of exploitation of children at work exist and persist, but they are particularly difficult to research due to their hidden, sometimes illegal or even criminal nature (3). In many situations, child workers jeopardize their health, their normal development, and even their lives (4). Currently, there is an international effort to increase the knowledge on child labour. This also includes the study of health hazards (5).

There is a general recognition about the need for epidemiological studies on the health aspect of child labour in order to contribute to the identification and implementation of feasible and effective strategies not just to promote the eradication of child labour, but also to reduce the impact on the present and future health status of child workers (6-8).

Child labour in figures

The International Labour Office (ILO) estimated that, globally, around 211 million children between 5 and 14 years were working in year 2000. Among those, 206 millions were living in developing countries (1). In Central America and the Dominican Republic there are about 2.4 million children who are presently working, representing 17% of all children aged 5-15 years in the region. About 80% of them are engaged in working activities which are prohibited for children by national legislation or international conventions due to their hazardous nature (9). In Nicaragua, it has been estimated from data of the National Child and Adolescents Labour Survey (ENTIA 2000) that 250,000 children aged 5-17 years were working in year 2000. Of these, 37% began working before the age of 10, and 34-68% were involved in hazardous work (10).

Working at waste disposal sites

-One of the worst forms of child labour.

There is an international effort to identify the worst form of child labour, those works or activities which by their nature or the circumstances are likely to harm the health, safety or morals of children, in order to enforce their immediately elimination (11). Worldwide, working at waste disposal sites is considered as one of the worst forms of child labour (12).
In Latin America, there are hundreds of thousands of adults and children working in an informal way at open waste disposal sites (13-18), typically living adjacent to the site or even inside the area, in poor housing conditions with minimal basic infrastructure for clean water and sanitation. Waste sorting and recycling activities are typically conducted in micro- and small scale enterprises, sometimes organized by families, with old equipment and virtually no dust control or worker protection. Some national and international agencies claim that most of the people working at such places are children under 16 years old. However, there is not data on the actual number of persons working in those places, since due to the complex nature of the phenomenon, it is extremely difficult to obtain reliable statistics (14).

Health hazards in child workers at waste disposal site

Children working at waste disposal sites face many health hazards and risks (14). These include the environmental conditions in which the work is carried out, the exposure to environmental contaminants and hazardous chemicals, accidents, and the many social problems related to human survival in places where municipal wastes are deposited. It is well known that due to their particular characteristics children may be more vulnerable to the threats posed by such situations. Although the presence of many health hazards is recognized, there is a lack of estimation of the magnitude of such problems.

Chemical exposures

Several publications had reviewed information on different potentially adverse effects on workers at waste incinerator and landfill sites as well as on the population from communities located nearby (19-24). In workers at those sites information is mainly based upon self reported symptoms (23), but not systematically recorded. However, although a great number of studies have been carried out, evidence of a causal relationship between specific health outcomes and landfill exposures is still inconclusive (20,23,25), perhaps due to the limitation on the studies design and the complexity of the phenomenon.

Biomonitoring studies are valuable tools for risk assessment and can demonstrate exposure of individuals to specific substances (26,27). Among the many environmental contaminants encountered at waste disposal sites for which biomarkers of exposure exist, lead is of special concern (28). Also, a potential risk of exposure to other toxic heavy metals like mercury and cadmium is present (20,24,28,29). Additionally, it has been proposed that
the exposure to persistent organohalogen pollutants, such as organochlorine pesticides, polychlorinated biphenyls (PCBs), and dioxin compounds (30) during uncontrolled burning of waste is likely to occur at waste disposal sites, therefore theses substances should be considered as priority pollutants in waste disposal sites investigation (24,31). Recent studies had indicated that waste disposal sites are potential sources of polybrominated diphenyl ether (PBDE) flame retardants (32), polychlorinated dibenz-p-dioxins and polychlorinated dibenzofurans (30).

Also markers of adverse health effects have been described, including markers of kidney and liver function and markers of molecular or chromosomal damage (24,31).

These studies are far more sensitive than studies of disease incidence. However, as pollutants often originate from more than one source, it has been difficult to attribute specific biomarkers to landfill emissions.

Heavy metals

Childhood lead (Pb) exposure constitutes a well-recognized environmental hazard (for comprehensive reviews see Skerfving 2005 (33), WHO/IPCS 1995 (34) and ATSDR 1999 (35)). The developing central nervous system is especially sensitive, and impairment of mental development has been associated with lead exposure, without evidence of any threshold level (33,36-38). Not only fetal and infant exposure, but also exposure later during childhood may affect cognitive development (36). The 1991 Centers for Disease Control (CDC) statement on childhood lead poisoning set 100 \( \mu \text{g}/\text{l} \) as a screening action guideline, and a management tool on community level (39,40); it does not imply that levels below are “safe”. Recent data suggest cognitive effects (37) below this level, and subtle neurodevelopmental effects (38) have been reported at fetal exposure levels as low as 50 to 60 \( \mu \text{g}/\text{L} \).

The predominant sources of lead vary from country to country. Point industrial sources may dramatically increase air and soil lead levels in countries where environmental controls have not been effectively implemented (41). Lead contaminations from small-scale enterprises that recycle lead, often in backyards, are a great problem in Central America and elsewhere. Leaded gasoline and household exposure through glazed pottery are other well-known sources of lead (42,43). Very little investigation on waste disposal sites as sources of lead has been carried out in Latin America, but some data from Brazil have been reported (44,45).
Exposure to mercury (Hg) is still a health hazard throughout the world today (46). Methylmercury, the most widespread source of Hg exposure, is most commonly the result of consumption of contaminated foods, primarily fish (47). Women of childbearing age are of particular concern because of the potential adverse neurologic effects of Hg in fetuses (48-50). The U. S. Environmental Protection Agency established a reference dose (RFD) (51), an estimated level assumed to be without appreciable harm, corresponding to a concentration of 5.8 µg/l Hg in cord blood (52-54). For metal mercury, the critical effect is renal toxicity (55,56).

For cadmium (Cd), renal toxicity is the critical effect (57,58). Recent data indicate that adverse health effects of cadmium exposure may occur at lower exposure levels than previously anticipated, primarily in the form of kidney damage (59) but possibly also on bone metabolism (60). Cadmium compounds are currently mainly used in rechargeable nickel-cadmium batteries. Cadmium emissions had increased dramatically during the last century, one reason being that cadmium-containing products are rarely recycled, but often dumped together with household waste. Cigarette smoking is a major source of cadmium exposure. In non-smokers, food is the most important source of cadmium exposure (57).

Selenium is an essential trace element involved in several key metabolic activities via selenoproteins, enzymes that are essential to protect against oxidative damage and to regulate immune function (61). The concentration of selenium (Se) in human and organism varies widely between geographical areas depending on its content in soil and plants, dietary Se intake, bioavailability and retention, mineral interactions and other factors. While Se-deficiency diseases have been recognized for some time, evidence is mounting that less-overt deficiency can also cause adverse health effects (61). In the context of these effects, low or diminishing Se status in some parts of the world, notably in some European countries is giving cause for concern (62). There is yet an almost complete lack of information on Se status in humans in Central and Latin America (63).

**Persistent organochlorine pollutants (POPs)**

Persistent organochlorine pollutants (POPs) are chemicals accumulating in lipids in living organisms and increasing in quantity up the food webs. In non-occupationally exposed human populations exposure to POPs comes mostly from dietary sources but occasionally also through inhalation of contaminated
soil and dust. Twelve POPs, including 9 pesticides, have been identified by the United Nations Environment Programme as powerful threats to the health of humans and wildlife and have been targeted for elimination (64).

Some toxic chemicals such as polychlorinated biphenyls (PCBs), which have been banned or restricted in the developed countries, may still be used in developing countries (65). Also, there is a problem of uncontrolled storage of obsolete stocks. Reports on PCBs levels in children from Central and Latin American countries have not yet been published.

It seems that the levels of chlorinated pesticides that were widely used in the past are now declining in many parts of the world because of regulatory measures such as banning and use restriction (65-67). Organochlorine pesticides have been reported to be present in agricultural areas in all Central American countries. 4,4’-DDT and its metabolites, aldrin, lindane, and endosulphane have been the most widely reported pesticides in different levels of the ecosystems (68). However, most data are from the 1980’s. In the traditional cotton growing areas of Nicaragua traces of POPs, mainly organochlorine pesticide, have been detected in cow’s milk (69), sediments (70), water (71), soil (72), and in human adipose tissue (73,74), cord and venous blood (74), and in breast milk (74,75).

Some studies on the level of organochlorine pesticides in children from Latin America are presented in Table 1. Data from urban regions are scarce.
Table 1. Concentration (ng/ml f.w.) of reported persistent organochlorine pollutants (POPs) in children from Latin America.

<table>
<thead>
<tr>
<th>Area / Country and Year of sampling</th>
<th>Subjects</th>
<th>Biological media</th>
<th>POP</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiapas, Mexico 2002 (76)</td>
<td>Children living in a rural malarious area, aged 6-12 years</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>13.7</td>
<td>3.8 - 40.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDE</td>
<td>38.4</td>
<td>5.7 - 115</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDD</td>
<td>2.1</td>
<td>nd - 14.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ DDT</td>
<td>54.3</td>
<td>13.4 - 142</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ DDE</td>
<td>0.8</td>
<td>0.6 - 1</td>
</tr>
<tr>
<td></td>
<td>9 males</td>
<td></td>
<td>6 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Luis Potosí, México 2002 (76)</td>
<td>Children living in an urban non-malarious area, aged 6-12 years</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDE</td>
<td>0.7</td>
<td>0.5 - 1</td>
</tr>
<tr>
<td></td>
<td>2 males</td>
<td></td>
<td>4 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chiapas, Mexico 1998 (77)</td>
<td>Children living in a malarious community. (Active DDT application at the moment of sampling), aged 6-14 years</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>67.8</td>
<td>21.8 - 113</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDE</td>
<td>86.7</td>
<td>50.3 - 167</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDD</td>
<td>1.9</td>
<td>0.7 - 3.3</td>
</tr>
<tr>
<td></td>
<td>7 males</td>
<td></td>
<td>2 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oaxaca, México 2000 (77)</td>
<td>Children living in a malarious community (Last DDT application 2 years before), aged 3-13 years</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>20.4</td>
<td>7.5 - 53.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDE</td>
<td>74.5</td>
<td>34.9 - 180</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDD</td>
<td>1.9</td>
<td>0.5 - 5.1</td>
</tr>
<tr>
<td></td>
<td>12 males</td>
<td></td>
<td>16 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isota, Choluteca, Honduras 1998 (78)</td>
<td>Children living in an urban area aged 15-18 years</td>
<td>Serum</td>
<td>4,4'-DDE</td>
<td>51% &gt;3.5</td>
<td>1.2 - 96.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aldrin</td>
<td>23% &gt;0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 males</td>
<td></td>
<td>30 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cubatão, SP, Brazil2,3 (79)</td>
<td>Children living in open-air dump area (Pilões community), aged 0-9 years</td>
<td>Serum</td>
<td>DDT</td>
<td>2.7</td>
<td>0 - 27.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>2.3</td>
<td>0 - 34.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.8</td>
<td>0 - 4.4</td>
</tr>
<tr>
<td></td>
<td>44 males</td>
<td></td>
<td>18 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children living in open-air dump area (Pilões community), aged 10-19 years</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>7.0</td>
<td>0 - 56.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>1.7</td>
<td>0 - 18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.7</td>
<td>0 - 4.7</td>
</tr>
<tr>
<td></td>
<td>29 males</td>
<td></td>
<td>20 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children living in a control area (Coata 200 district), aged 0-9 years</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>1.7</td>
<td>0 - 8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>2</td>
<td>0 - 11.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.6</td>
<td>0 - 2.4</td>
</tr>
<tr>
<td></td>
<td>53 males</td>
<td></td>
<td>28 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children living in a control area (Coata 200 district), aged 10-19 years</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>4</td>
<td>0 - 46.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>0.01</td>
<td>0 - 0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.2</td>
<td>0 - 5.7</td>
</tr>
<tr>
<td></td>
<td>31 males</td>
<td></td>
<td>23 females</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children living in a control area (Coata 200 district), aged 10-19 years</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>0.5</td>
<td>0 - 4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>0.03</td>
<td>0 - 0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>53 males</td>
<td></td>
<td>28 females</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

f.w. = fresh weight, nd= not detected, Σ DDT= DDT + DDE + DDD, Σ HCH= α-HCH + β-HCH + γ-HCH

1 geometric mean
2 No year of sampling is given.
3 Φ= nd, in this study concentrations below the detection limit were assumed as zero for calculation purpose.
Polybrominated diphenyl ethers (PBDEs)
Polybrominated diphenyl ethers (PBDEs) have been extensively used as additive flame retardants since the 1970s. PBDE levels increasing with time have been found in most environmental compartments, including aquatic and terrestrial ecosystems, and in humans (80-82). Most data originate from Europe, North America and the Arctic. From Asia there are reports from Japan, Korea, and Singapore, and some data from Australia. Information on human PBDE exposure from other regions in the world, except one report from Mexico (83), is still entirely lacking.

Human exposure arises from contaminated food (84), but in contrast to the traditional POPs, inhalation/ingestion of dust is also a likely route of exposure (85), because small amounts of these substances may leach out of consumer goods. It is also likely that prenatal and postnatal exposure through breast milk (86-88) may occur, as for the traditional POPs, but there is still a lack of knowledge concerning the importance of these routes.

PBDEs are of concern because of their high lipophilicity and high resistance to degradation processes. The occurrence of high concentrations of PBDEs in the environment may be sufficient to elicit adverse effects in wildlife. So far, knowledge on the toxicity of PBDEs is limited to a few congeners. Hepatotoxicity, embryotoxicity and thyroid effects seem to be characteristic endpoints in animal toxicity, and behavioral effects have been demonstrated (89). There is also concern that levels could cause adverse effects in sensitive human populations, but human data on adverse effects are yet entirely lacking (90,91).

Production and processing facilities may discharge PBDEs to the environment, and high levels have been found in biota downstream of certain industries (81). However, releases of PBDEs can also occur from some products throughout their life cycle, during recycling, and after disposal to landfills (92,93).

There is a lack of data on importation and use as well as disposal processes and handling of PBDEs-related products in Nicaragua.
Injuries at the work place

Injuries constitute one of the greatest threats for child workers. At the end of the 90’s, ILO carried out a large survey on child labour in Philippines. This study estimated that 12 % of all children engaged in economic activity had suffered work related injuries during their working life. ILO also calculated that overall 24 % of all child workers had experienced either work related injuries (WRIs) or illness, out of which 3 % stopped work permanently due to work related injuries or illness, and 50 % were obliged to do it temporarily (94). In Nicaragua, it has been estimated from data of the National Child and Adolescents Labour Survey (ENTIA 2000) that about 14 % of the child workers had suffered WRIs (10). Among those, 21 % temporarily stopped working, and 8 % were hospitalized. However, globally, evidence on the short term and long term health consequences of child work activity is very limited.

There is an inadequacy of information currently available about childhood occupational injuries and there is a need for research in several critical areas. These included the nature and consequences of work injuries (occurrence, pattern, typology and severity), as well the circumstances of occurrence. This information is necessary as a basis for developing effective education, primary prevention, and intervention programs (7,95).

Traditional assessments of work-related injury are developed for adults. This may be an inadequate method of examining work related injuries in children. The situation is even more complicated in countries where no systematic information is collected on work related injuries in children. This is especially true regarding the worst forms of child labour, which by their very nature are often hidden from public view and scrutiny (7,96). Thus, the development of injury prevention programs for children requires a clear distinction from adult injury patterns. Without knowledge of the basic epidemiology of injuries, effective injury prevention cannot be carried out.
Aims of the thesis

To assess the occupational and environmental exposure to heavy metals, persistent organochlorine pollutants, and polybrominated diphenyl ethers in child workers at a waste disposal site, and in referent populations.

To describe the occurrence and estimate the risk of having work-related and non-work-related injuries in child workers at a waste disposal site, and in referents

and

to construct a typology of work related injuries at the waste disposal site based on those injury characteristics related directly with the injured child, in order to identify factors for prevention.
Area description

Managua waste disposal site

In Managua, the capital of Nicaragua, the municipal domestic and industrial waste disposal site “La Chureca” is located in the neighbourhood Acahualinca, on the south shore of lake Xolotlán, covering an area of 7 km$^2$. La Chureca, the biggest waste disposal site in the country, was created 40 years ago. Approximately 1000 persons worked at the waste disposal site in 2001, of which 50% were under age 18. Some of them also lived there (18). Currently, more than 115 families are living at the waste disposal site.

Recollection, classification, selling, storing, and cleaning of recyclable waste are the most common activities. Children usually are involved in more than one activity, most frequently handling glass, metals, and plastic. Often, the material is stored at home. Recollection of food from the waste disposal site for self-consumption has also been reported. A thick cloud of smoke covers the area since the waste is burned to retrieve iron and other materials. The waste is not compressed, the sun is intense, and a constant breeze from the lake sweeps the area. Thus, substantial amounts of airborne dust are generated.

Figure 1. Map of Managua, Nicaragua. Locations of urban Managua and waste disposal site area are given. (Elaborated by Emilie Stroh).
Material and methods

Study populations
The study and reference groups were established with the help of local non-governmental organizations working in child labour eradication programs, “Centro Dos Generaciones” and the “Chateles” project. The field work was prepared in the beginning of 2002, and carried out during May and June 2002.

Centro Dos Generaciones, which has worked with child workers at the waste disposal site since 1992, estimated that around 570 children under 18 years were working there in 2001 (18). In April 2002 Centro Dos Generaciones enrolled in its community program 438 children that regularly worked at the waste disposal site, and had a family. All current child workers were identified who: a) had worked at the waste disposal site for at least one year, b) were of age 6-15 years, and c) lived at the waste disposal site or in a neighbourhood nearby, Acahualinca (n= 117) (97).

Additionally, by consulting the student register at the local public primary school and with assistance from Dos Generaciones, a list was elaborated of all children presently attending the local primary school in Acahualinca, aged 6-15 years, who lived in Acahualinca and had never worked at the waste disposal site (n= 150).

Another group of children from the south and central areas of Managua, 10-20 km away from Acahualinca, who did not work at the waste disposal site were recruited with support from the Chateles project. This project attends 250 children under age 16, with poor socioeconomic situation. All children aged 6-15 years were identified (n= 156), and a convenience sample of 34 children were selected to be invited.

Each identified child's family was visited by the research team with help from the personnel of Dos Generaciones and Chateles project. Parents and children were given information on the aims and procedures of the study during several meetings, and a written consent was obtained. The participation rate was high (n=103) for the child workers at the waste disposal site (study group). The participation rate was lower (n= 102) for children in the reference group. All invited children from the Chateles project participated.
For paper I-III we considered five groups of children. A flow chart describing the groups in each study, which were defined according to work history, place of living and fish consumption habits, is given in Figure 2. In paper IV only child workers at the waste disposal site and referents from Acahualinca were included.

Non-participants

Based on registers from Dos Generaciones and Chateles project and information obtained during the family visits, data on age, sex, school attendance, and work status was also recorded for non-participants. Among child workers who rejected to participate \((n=14)\), six were living at the waste disposal site and the rest in Acahualinca.

The distributions of sex and age of these children were comparable to the participants. For the reference children living in Acahualinca the distributions of sex and age were also similar to the participants. None of them were involved in informal or formal working activities at the time of the field work.

Data collection

Interviews

Participants attended the local office of Centro Dos Generaciones, where trained staff personally interviewed them following structured questionnaires. When children were younger than 10 years, help from the parents was required. Otherwise children attended the interviews in private. The interviews were performed on the same day, in the morning (background questionnaire) and in the afternoon (injury questionnaire). Regular check-ups with all interviewers were performed during the fieldwork period.

Background questionnaire (Paper I, II, III and IV)

Detailed information on demographic characteristics, common daily activities, material handling, and work history was collected. Also, information on duration of dwelling and basic housing conditions such as water and electricity was obtained. Dietary habits, especially fish consumption, were assessed. We also asked about present and previous contact with car batteries at work, at home and in the residential area. After this interview the blood sampling was performed.
Injury questionnaire (Paper IV)

Children were asked to recall all events that caused injury of any kind during the past 12 months, leading to at least one day of absence from work or school, excluding the day of the event. We also asked about injuries during the past 3 years, but these data are not reported here. The interview consisted of a narrative description of each such occasion from the child, which was recorded by the interviewer, followed by a child-oriented injury characterization by use of a check-list questionnaire based on recommendations by the International Labour Organization (95,96). The check list collected information on type of injury, primary causal agent, injured body part, number of days of absence from work or school, and persistent functional impairment or disability related to the injury (yes/no).

Blood Sampling

For determination of metals (Paper I), 5 ml of blood was drawn from the cubital vein into evacuated sodium heparine tubes (Vacutainer, Rutherford NJ). The tubes were stored in refrigerators until analysis in Sweden. Each individual sample was analyzed.

For determination of lipids, POPs (paper II), and PBDEs (Paper III), 15 ml of blood were required from children older than 10 years. The samples were drawn into plain evacuated tubes (Vacutainer, Rutherford NJ) and centrifuged. Around 5 ml of serum were transferred to acetone-washed glass bottles, and the remaining serum was transferred into a small plastic tube. Serum samples were frozen and kept at -20°C, until analysis in Sweden.

The subjects were stratified by waste disposal site work experience, area of living, and fish consumption, and five distinct serum pools were prepared. Criteria, and individuals included in the pools are described in Figure 2.

No individual samples were analyzed.

Soil sampling

An exploratory soil sampling at the waste disposal site, La Chureca, and at the nearby residential area, Acahualinca, was performed in February 2004 to investigate potential point emissions sources of lead, and diffuse lead contamination (paper I).

We collected composite soil samples from 16 places at the waste disposal site and 17 places from Acahualinca. The sampling strategy was in accordance
with recommendations by USA Technical Review Workgroup for Lead (98) and EPA (99,100).

**Chemical analysis**

**Determination of metals (Pb, Hg, Cd, Se and Fe) in blood**
The concentrations of Pb, Cd, Se, and Fe were determined by inductively coupled plasma-mass spectrometry (Thermo X7, Thermo Elemental, Winsford, UK). The samples were prepared according to Bárány et al (101). The limits of detection were for Pb 0.18 µg/l, Cd 0.02 µg/l, Se 2.0 µg/l, and Fe 254 µg/l.

The determination of Hg was made in acid-digested samples by cold vapour atomic fluorescence spectrometry (102). The limit of detection was 0.23 µg/l. The analytical accuracy for all analyses was checked against reference materials. All analyses were performed at the Department of Occupational and Environmental Medicine, Lund University.

**Determination of metals in soil**
Incidental ingestion is the major pathway of exposure to metals in soil and dust. This is best represented by the metal concentration in the fine fraction. For that reason each composite soil sample was passed through a 250 µm sieve. The fine fraction was collected. About 1 gram was balanced and then 30 ml conc. Nitric Acid was added. The samples were then refluxed boiled for about 72 hours. At the end the acid was boiled away, and 5 ml was left and then the sample was diluted with Milli-Q water to 50 ml. The complete procedure is described elsewhere (103).

The analyses were performed at the Department of Plant Ecology and Systematics at Lund University.

**Determination of persistent organochlorine pollutants and PBDEs in serum**
The chemicals used, extraction of serum, lipid determination, partitioning with an alkaline solution, procedure and analysis were performed as described by Hovander et al (104), except that n-hexane was replaced with cyclohexane for the PBDE-analysis (Paper III; see also (105)). Lipids were removed from the extracts by sulfuric acid. Fractions containing both the neutral and phenol type substances were subjected to cleanup on sulfuric acid silica gel columns. The mobile phase for phenolic compounds was dichloromethane. Additional
cleanup was made for both fractions on an activated silica gel column. All solvents were of the highest available commercial grade.

Identification and quantification were performed using a GC-MS Finnigan TSQ 700 (Thermoquest, Bremen, Germany) operating in electron capture chemical ionization (ECNI) mode. For POPs (Paper II) authentic reference standards, mostly synthesized in house, were used as standards. The surrogate standards were: CB199, used for analysis of neutral compounds and 4-OH-CB193 and 2,4,5-trichlorophenol for halogenated phenolic compounds (HPCs). Injection standards (CB199 for phenol fraction, CB189 for the neutral fraction) were used for quantification and calculation of the recovery to evaluate the reproducibility of the method (106). For PBDEs (Paper III; see also (105)) authentic reference standards synthesised in house, were used.

In paper II results were presented both on fresh weight basis, and adjusted for lipid weight. Determinations of lipid weight (l.w.) were done gravimetrically after complete evaporation of the solvent. Results were reported on weight to weight basis, which is reasonable as most substances that were measured have molecular masses in the same range.

In Paper III we chose to report only lipid adjusted concentrations on molar basis, as the molecular weight of low and high brominated congeners vary considerably.
Data analysis

Paper I
Blood and soil levels of the investigated heavy metals are presented as medians, ranges, and percentiles. For testing of group differences, the Mann-Whitney U-test and ANOVA test were used. The influence of age, sex, and duration of work at the waste disposal site on blood metal levels was also explored in uni- and multivariate linear regressions, using the change-in-estimate-method suggested by Greenland for selection of covariates (107). As blood lead levels are related to the hemoglobin (B-Hb) content we used B-Fe as a surrogate for B-Hb, which was not available, and repeated all analyses using instead the B-Pb/B-Fe ratio. The findings did not change, thus, we report only unadjusted B-Pb levels.

Paper II and III
A study design with pooled samples was used to investigate the exposure level of POPs and PBDEs in children, since for ethical and economical reason analyses of individual samples were not feasible. The exposure levels obtained in the pooled samples are equivalent to mean group levels.

Paper IV
Injury risk estimation
In a first step, we conducted a descriptive analysis where the unit of analysis was the individual child. The risk of having an injury was estimated using odd ratios (OR) and 95 % confidence intervals (95 % CI) calculated by logistic regression (SPSS for Windows version 12.0.1). In a second step, injury incidence rates (IR), rate ratios (RR) and 95 % confidence intervals (95 % CI) were estimated for child workers and referents by Poisson regression (EGRET for Windows version 2.0). Incidence rates for work related injuries and non-work related injuries were calculated separately, classified as follows: a) Work related injury (WRI): any personal injury, resulting from an event occurred at the work place including acts of violence (96). b) Non-work related injury (Non-WRI): any personal injury, resulting from an event occurring out of the work place, not linked with the main occupational activities. Injuries related with domestic activities at home were included in this category. We considered age and sex as potential confounders; in internal comparisons among the child workers work hours and school attendance were also
considered. The change-in-estimate-method suggested by Greenland (107) was used.

**Classification of work related injuries (WRIs)**

In order to classify WRIs into homogenous groups of injury typology (classes) a two-step cluster analysis was performed. The final classification of those variables that were used in the cluster analysis was performed by one person (S N Cuadra), using all information encoded in the interview forms. Based on previously proposed theoretical frames for injury classification (7,95), only those variables that were related to the injured person were considered for the identification of classes. The variables included within the cluster analysis were: type of injury, body part injured, and lost workdays (categorized; used as an indicator of the severity of the injury). When more than one type of injury was reported from a single event, the most severe type of injury and the injured body part related to it was determined based on the child’s own perception as expressed during the interview. Since the cluster analysis works best on large groups, the variables representing type of injury and injured body part were aggregated. The two-step cluster analysis was performed using SPSS for Windows version 12.0.1 software (SPSS Inc. 2003). SPSS uses an agglomerative hierarchical clustering approach as described by Landau and Everitt (108). As a measure of similarity between cases (injuries) the log-likelihood distance was selected since this can handle both categorical and continuous variables.

**Ethical approval**

The Ethic’s committees at Lund University and The National Autonomous University of Nicaragua-Managua (UNAN Managua) approved the study protocol, and a written informed consent was obtained from the participants and guardians.
Results and comments


Paper I

Blood levels of lead, mercury, cadmium, and selenium

The children working at the waste disposal site had higher levels of B-Pb, compared with the non-working referents groups (Table 3). There was also a clear gradient for B-Pb between non-working children from Acahualinca, and those from the remote urban area. Neither the duration of work at the waste disposal site nor any reported history of contact with car batteries were related to the levels of lead in the children. Age had no significant influence on B-Pb levels. As observed before (109,110), in all study groups boys had approximately 30-40% higher B-Pb levels than girls.

Among child workers at the waste disposal site (group 1+2) as many as 28% had B-Pb higher than the community action level 100 µg/l recommended by CDC (Table 2) (39,40). However, it should also be noted that as many as one third of the non-working children in Acahualinca had levels above 50 µg/L, a level at which subtle developmental and cognitive effects had been suggested (33,36-38,111,112).

Table 2. Blood Lead level (B-Pb) in children working at waste disposal site and referents.

<table>
<thead>
<tr>
<th>B-Pb concentration (range)</th>
<th>Children working Group 1+Group 2</th>
<th>Children non-working, living nearby Group 3+Group 4</th>
<th>External referent groups Group 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median 73 (17-423)</td>
<td>40 (11-138)</td>
<td>28 (11-68)</td>
<td></td>
</tr>
<tr>
<td>&lt; 50 µg/L</td>
<td>23 22</td>
<td>65 64</td>
<td>32 94</td>
</tr>
<tr>
<td>50-99 µg/L</td>
<td>51 49</td>
<td>35 34</td>
<td>2 56</td>
</tr>
<tr>
<td>≥100 µg/L</td>
<td>29 28</td>
<td>2 2</td>
<td>0 0</td>
</tr>
<tr>
<td>Total</td>
<td>103 100</td>
<td>102 100</td>
<td>34 100</td>
</tr>
</tbody>
</table>
The children working at the waste disposal site also had higher levels of B-Hg and B-Cd compared with the non-working referents groups, but the levels observed (Table 3) were much lower than those levels at which adverse health effects have been observed (48-50). There may well be different proportions of organic and inorganic mercury in the different study groups. Exposure to inorganic mercury at the waste disposal site perhaps occurs, but as we chose to determine total-Hg only, this cannot be distinguished. There were no gradients between non-working children from Acachualnca, and those from the remote urban area for B-Hg and B-Cd. Age had no significant influence on metal levels. Selenium status was good in all groups (61,113).

**Mercury and fish consumption from lake Xolotlán**

Fish from lake Xolotlán is an important part of diet for the population living nearby the waste disposal site. As expected (47), consumption of such fish influenced the B-Hg levels in children not working at the waste disposal site. Overall, the additional effect of one fish meal from the lake per month was estimated to be 0.2 (95 % CI. 0.1-0.3) µg/l. Such an estimate does not justify restrictive fish consumption advisories from the mercury contamination point of view.

**Investigating sources of lead contamination**

The exploratory soil sampling at the waste disposal site and the nearby residential area, Acachualnca, seems to indicate a gradient on lead soil content, which supports the presence of the waste disposal site as a source of lead contamination (Figure 3). The lead content in soil at homes at the waste disposal site was higher than the lead content in soil in Acachualnca homes, however not reaching statistical significance. Similarly, the common areas at the waste disposal site were indicated to have higher soil Pb levels than in Acachualnca, whereas the lead content in soil from the school playgrounds did not differ.

It is well known that artesanal car battery workshops are sources of occupational and paraoccupational lead exposure (41,42,114-118). Regulation of artesanal car battery workshops have been enforced by health authorities in Nicaragua since 1998, but we identified a few places in Acachualnca at which battery handling had taken place or still were said to occur, which also had high soil Pb-levels (Figure 3). Some children referred to own (n=11; 15 %) or family (n= 28; 27 %) handling of car batteries in the
interview, but we observed no impact on their B-Pb-levels – this may merely reflect that our question was not sensitive enough.

Figure 3. Lead content in soil (ppm, µg/g) from homes located at Managua waste disposal site and from the nearby area, Acahualinca. Median level of soil lead content is also given for homes at the waste disposal site and Acahualinca neighbourhood.
**Table 3.** Blood concentration (µg/L) of lead and others heavy metals in children working at the waste disposal site, and referents.

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>Hg</th>
<th>Cd</th>
<th>Se</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µg/l</td>
<td>µg/l</td>
<td>µg/l</td>
<td>µg/l</td>
<td>mg/l</td>
</tr>
<tr>
<td>Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of subjects</td>
<td>Waste disposal site</td>
<td>M</td>
<td>P10</td>
<td>P90</td>
<td>M</td>
</tr>
<tr>
<td>Group 1</td>
<td>42</td>
<td>1 (0-12)</td>
<td>Work, live</td>
<td>77.4</td>
<td>43.3</td>
</tr>
<tr>
<td>Group 2</td>
<td>61</td>
<td>1 (0-12)</td>
<td>Work</td>
<td>66.2</td>
<td>36.6</td>
</tr>
<tr>
<td>Group 3</td>
<td>59</td>
<td>2 (1-8)</td>
<td>No</td>
<td>39</td>
<td>22.9</td>
</tr>
<tr>
<td>Group 4</td>
<td>43</td>
<td>0</td>
<td>No</td>
<td>42</td>
<td>22.1</td>
</tr>
<tr>
<td>Group 5</td>
<td>34</td>
<td>0 (0-4)</td>
<td>No</td>
<td>28</td>
<td>15.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groups</th>
<th>p-value</th>
<th>p-value</th>
<th>p-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1+2 vs 3+4+5</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p=0.003</td>
</tr>
<tr>
<td>Group 4 vs 5</td>
<td>p=0.001</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

nd = no detected; P10= percentile 10; P90= percentile 90

1median (range)

2Mann-Whitney U-test, p-values above 0.2 are not given
**Paper II**

**Exposure to persistent organochlorine pollutants (POPs)**

The children working at the waste disposal site had higher levels of 4,4′-DDT, 4,4′-DDE, γ-HCH, several PCB-congeners, PCP and 4-OH-CB187, compared to the non-working reference groups (Table 4).

An increased level of PCP was also observed among the children who lived and worked at the waste disposal site. In children not working at the waste disposal site there were also gradients for several POPs, according to vicinity to the dump, and to fish consumption.

The high 4,4′-DDE/4,4′-DDT ratio observed suggests that the exposure to DDT in our study group is not from recent application (66,67). The group differences are reasonable, as 4,4′-DDT is known to have been more extensively used for vector control at the waste disposal area than in the central urban areas.

The levels of 4,4′-DDE found in our study are lower than the levels reported in children from a malarious area in Mexico with a history of recent or current application of 4,4′-DDT for vector control (see Table 1), but much higher than those reported in children from developed countries (Figure 4).

There are evidences that the levels of PCBs have been decreasing during the last decades in industrialized countries (119). Time trend data from Central America do not exist. The CB153 levels observed among urban poor children not working at the waste disposal site were higher than the levels reported in children from Germany and United States (Figure 4).

In general, our data suggest an occupational and environmental exposure to POPs in children at the waste disposal site. Consumption of fish from lake Xolotlán also may influence the levels of some POPs such as PCBs. However, the levels observed were clearly lower than those at which adverse health effects have been reported (120-122).
Figure 4. Serum concentration of 4,4’-DDE and CB153 in Nicaraguan children (pooled samples) and children from developed countries. Pool 3: Poor children (11-15 years) living nearby a waste disposal site in Nicaragua with low to moderate fish consumption. Pool 4: Poor children (11-15 years) living nearby a waste disposal site in Nicaragua, no fish consumption. Pool 5: Poor children (11-15 years) living in urban Managua, far from the waste disposal site, no fish consumption. USA 2001/2002: Children and adolescents (12-19 years) from general population. In this group the 50th percentile for CB153 concentration was below the maximum limits of detection (LOD), which was reported to be 10.5 ng/g l.w. Thus, LOD and 95th percentile for CB153 and 50th and 95th percentiles for 4,4’-DDE are plotted (123). Germany 1998: Children (9-11 years) from general population (124). 4,4’-DDE and CB153 median and 95th percentile concentrations for German children were given in ng/ml f.w., therefore values were transformed into ng/g l.w., assuming a serum lipid content of 0.6 %.
Paper III

Exposure to PBDEs

In all pools BDE-47 was the dominating PBDE congener, followed by BDE-99, BDE-100 and BDE-153. Thus, the congener profile suggests exposure mainly to the technical PentaBDE-product, but decaBDE (BDE-209) was also found in all pools.

The teenagers living and working on the waste disposal site had very high levels of low-medium brominated BDEs (Table 5), much higher than hitherto reported elsewhere. They were followed by those who worked at the waste disposal site, but lived in the nearby area (Table 5). Obviously, the waste disposal site is a source of exposure. The waste is burned, and high levels of dust are generated; thus inhalation is the likely main route of exposure.

PBDE-levels were higher among non-working teenagers eating fish from the lake, compared to the levels observed in non-consumers living in the same area (Table 5). Thus, fish from the lake may also be a source of exposure to low-medium brominated BDEs. This is in line with previous findings of a correlation of fish consumption and the level of BDE-47 (125), and estimates of dietary PBDE-exposure (126).
Table 4. Serum concentration (ng/g lipid weight [l.w.], ppb, and ng/g fresh weight, [f.w.], ppb) of some POPs in children working at the waste disposal site, and referents (pooled samples)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number of subjects</th>
<th>Fish meals/month median (range)</th>
<th>Waste disposal site</th>
<th>Lipid weight content (%)</th>
<th>Neutral fraction</th>
<th>Phenolic fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDE</td>
<td>4,4'-DDT</td>
</tr>
<tr>
<td>Pool 1</td>
<td>11</td>
<td>2 (0-8)</td>
<td>Work, live</td>
<td>0.36</td>
<td>1600</td>
<td>5.7</td>
</tr>
<tr>
<td>Pool 2</td>
<td>23</td>
<td>2 (0-8)</td>
<td>Work</td>
<td>0.37</td>
<td>1200</td>
<td>4.4</td>
</tr>
<tr>
<td>Pool 3</td>
<td>16</td>
<td>2 (2-8)</td>
<td>No</td>
<td>0.38</td>
<td>990</td>
<td>3.8</td>
</tr>
<tr>
<td>Pool 4</td>
<td>10</td>
<td>0</td>
<td>No</td>
<td>0.38</td>
<td>1000</td>
<td>3.8</td>
</tr>
<tr>
<td>Pool 5</td>
<td>11</td>
<td>0</td>
<td>No</td>
<td>0.38</td>
<td>990</td>
<td>3.7</td>
</tr>
<tr>
<td>LOQ2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt; 5</td>
<td>&lt; 0.02</td>
</tr>
</tbody>
</table>

1sum of CB118, 153, 105, 138, 187, 183, 128, and 180; 2LOQ, limit of quantification

Table 5. Concentrations of some PBDEs (pmol/g lipid weight [l.w.]) in teenagers working at a waste disposal site, and referents (pooled samples)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number of subjects</th>
<th>Fish meals/month median (range)</th>
<th>Waste disposal area</th>
<th>Lipid weight Content (%)</th>
<th>BDE-47</th>
<th>BDE-100</th>
<th>BDE-99</th>
<th>BDE-153</th>
<th>BDE-183</th>
<th>BDE-203</th>
<th>BDE-209</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool 1</td>
<td>1</td>
<td>2 (0-8)</td>
<td>Work, live</td>
<td>0.41</td>
<td>639</td>
<td>110</td>
<td>308</td>
<td>46</td>
<td>2.4</td>
<td>0.86</td>
<td>5.4</td>
</tr>
<tr>
<td>Pool 2</td>
<td>21</td>
<td>2 (0-8)</td>
<td>Work</td>
<td>0.38</td>
<td>70</td>
<td>18</td>
<td>19</td>
<td>18</td>
<td>2.4</td>
<td>0.70</td>
<td>3.6</td>
</tr>
<tr>
<td>Pool 3</td>
<td>15</td>
<td>2 (2-8)</td>
<td>No</td>
<td>0.37</td>
<td>29</td>
<td>7.3</td>
<td>11</td>
<td>4.5</td>
<td>1.1</td>
<td>0.40</td>
<td>5.7</td>
</tr>
<tr>
<td>Pool 4</td>
<td>7</td>
<td>0</td>
<td>No</td>
<td>0.40</td>
<td>11</td>
<td>2.0</td>
<td>4.6</td>
<td>2.2</td>
<td>2.6</td>
<td>0.47</td>
<td>7.3</td>
</tr>
<tr>
<td>Pool 5</td>
<td>8</td>
<td>0</td>
<td>No</td>
<td>0.43</td>
<td>14</td>
<td>3.4</td>
<td>6.5</td>
<td>2.6</td>
<td>1.0</td>
<td>0.50</td>
<td>6.0</td>
</tr>
</tbody>
</table>

1mean of duplicate analyses
**Paper IV**

**Injury occurrence**

Briefly, 66 child workers and 20 referents reported at least one injury during the last 12 months (odds ratio 7.4; 95 % CI 3.9 to 14). In total, 110 and 22 injuries, respectively, were reported. Among the child workers, most of the injuries occurred at the waste disposal site (n= 79; corresponding incidence rate of work related injuries 2.2 per 1000 person-days; (Figure 5). Seven (9 %) of the work related injuries resulted in persisting functional impairment or pain, i.e. approximately 0.07 per working year. It has to be kept in mind that our study most likely underestimates the true risk for work related injuries, as only presently active child workers were included.

The occurrence of Non-WRIs was similar in the study and referent groups. The incidence estimate for child workers is however slightly overestimated, as the person-years included in the calculations was defined as 365 days minus the number of days that the child was absent from work due to a WRI. For the referents 365 days observation period was used.

![Figure 5](image_url)  
**Figure 5.** Injury incidence rate in children working at the Managua waste disposal site, “La Chureca” and in referents from Acahualinca. The rate ratios (RR) and 95 % CI were calculated by Poisson regression.
Injury classes (typology)

A prerequisite for injury prevention is the identification of characteristics of both the injuries and their circumstances of occurrence. The two step cluster analysis revealed five injury classes. Class 1 and class 5 point to a particular part of the body (lower extremities, mostly feet) and a specific types of injury (open wounds and superficial injuries), with low or moderate severity. These two classes accounted for almost 50% of all investigated injuries in these children. Class 2 shares a similar pattern, but is affecting upper extremities and hands. Thus, these three classes together counted for 70% of all injuries. These injuries occurred mostly during the moment when children were collecting and classifying the material. If these classes of injuries could be totally avoided, the absence from work and school would be reduced by more than 500 days per year in 100 workers. Simple protective measures can reduce the risk for these injuries, since today many of the children wear no shoes at all during their work, and no one has access to gloves.

The class of injury that includes the most severe injuries (class 3; 11%) reflects a very dangerous situation. In order to be able to have access to saleable garbage children have to risk their life. They wait for the municipal garbage trucks at the entrance of the waste disposal site, and jump onto the moving truck in order to collect the so called best material. Moreover, most of the time they have to compete with adults to have this opportunity. Then, the risk is not only the risk of having an accident, but also to suffer violence.

Class 4 represents the least severe injuries (14%). This kind of injury could be produced by several modes of injury, including also fall at the same level when playing with other children, and violence from another person.
General discussion

Methodological issues

Selection
We aimed to enroll currently active child workers at the waste disposal site within the selected range of age. In order to achieve this, we identified all children by help from the NGO Centro Dos Generaciones which keep an updated register of child workers and their families, within the frame of a special program of prevention and eradication of child labour, which have existed for many years. Thus, the child workers at the waste disposal site included in the study represent the great majority of all child workers living with a family in the selected age category. Those children whose primary support are not a family or a family substitute or whose behaviour is at odds with community norms, e.g. street children and drug abusers, were thus not included. Such children may be engaged in different work at the waste disposal site, and likely to be more vulnerable, especially concerning the risk for injuries.

We compared the child workers with referents living in an area nearby the waste disposal site, with the intention of finding a close similarity in socioeconomic conditions. The populations in all the neighbourhoods surrounding the waste disposal site are characterized by low income, and have similar access to the health and education systems (127). The body mass index (BMI), blood iron content and blood lipid concentration in the child workers and the referents were comparable, indicating similar nutritional status (own data). Thus, we have indications that the desired similarity between groups was achieved.

As external referents in paper I, II, and III we enrolled children living far away from the waste disposal site, in central and south Managua. These children belonged to low income families, and did not have a history of current or previous work at the waste disposal site. The aim was to have a crude estimation of exposure levels in poor urban children, but not to get a representative population sample.

Census data for children do not exist in Nicaragua; thus we cannot evaluate the representability of our study groups in relation to the total population.
Among referents living in Acahualinca 11% reported informal work outside their home, a figure that is similar to overall estimates for Nicaraguan children (10). School attendance was very high in all groups, even higher than for other urban Nicaraguan children (10). This is explained by the recruitment of child workers at the waste disposal site through Centro Dos Generaciones, which has a special educational programme for child workers based on the concept that access to education is the most powerful tool to break the cycle of poverty, and by the recruitment of referents using either school registers or the register from Chateles project.

Selected subjects for POPs and PBDEs analysis

In paper II and III a study design with pooled samples was used. The reason for this was two-fold - for economical reasons we had no possibility to analyze individual samples for POPs and PBDEs in all subjects, and for ethical reasons we wanted to keep the amount of blood sampled as low as possible in this population of malnourished children and teenagers. Results from pooled samples are equivalent to mean group levels. Therefore, we have no information on the individual variation and thus no possibility for statistical testing. To overcome this limitation, we instead carefully selected the subjects to be included in the pools, in order to have them clearly different with regard to the primary factors that we wanted to investigate (work at the waste disposal site, area of living), but as homogenous as possible with regard to factors that we - based on previous knowledge from the literature - assumed would influence POPs and PBDEs levels (fish consumption, age).

Non-participants

The participation rate was lower in referents than in child workers at the waste disposal site. Our impression during the fieldwork was that the main reason for non-participation among referents was the blood-sampling, whereas the child workers at the waste disposal site and parents were more concerned about the chemical hazards investigated, and thus more prone to participate. Thus, regarding paper IV, we do not expect that the loss of participants among referents is differential with regard to injury prevalence. For assessment of blood levels of metals and persistent organic pollutants, the similarities between participant and non-participants concerning background factors suggest that selection bias is of minor importance.
**Information**

As in all questionnaire-based studies, the risk for recall bias has to be considered. Information on work, school attendance, and other non-occupational activities provided by children or their parents was corroborated with current records from the local institution Centro Dos Generaciones. Information from children living away from the waste disposal site was also corroborated with records from Chateles projects. Thus, the risk of misclassification regarding work status and residency is negligible.

In paper I, II and III we investigated the influence of fish consumption on the level of Hg (47,128) and POPs (120,129,130), and found constant relations with Hg and some POPs, as expected from the literature (131,132). We found that our question on fish consumption was easily understood by the subjects, and it was not in focus during the interview. Thus, even if there is some misclassification, the risk for differential misclassification of exposure is likely to be low.

During the injury interview focus was on all injuries, not only WRI. The occurrence and typology of Non-WRIs was similar in the study and referent groups. In both groups there were only one or two individuals that reported more than one Non-WRI. This speaks against over-reporting of injuries among child workers at the waste disposal site. Also, it speaks against an intrinsic injury-prone behaviour in child workers at the waste disposal site.

**Chemical exposure – findings and implications**

**The waste disposal site: a source of lead contamination**

Our study shows an evident exposure to hazardous levels of lead in child workers at the waste disposal site. A contemporary study performed in child workers at the waste disposal site also reported levels of lead that were in the same range to the level found in our study, with around 25% of all children having higher level than 100 µg/l (133).

We observed a gradient on lead level according not only to working status, but also to vicinity to the dump. One third of referent children living nearby in Acahualinca had B-Pb levels exceeding 50 µg/L, whereas only few children in the reference group from central Managua exceeded this level. The neighbourhood characteristics of Acahualinca - a very poor community, lacking infrastructure and roads - implies that vehicle traffic intensity is very low. Also, during the last 10 years the use leaded gasoline in Nicaragua has
been restricted (134) as part of a regional initiative in Central America. Thus, it seems likely that the waste disposal site, also by environmental exposure, influences the levels of B-Pb in the Acahualinca children.

There is yet little data on lead exposure in the general population in Managua. Clearly, in our study B-Pb levels in children living far away from the dump were lower than the levels observed in children from urban areas in Mexico, Brazil and Argentina (42). However, comparisons are difficult to establish since most of data are from the 90’s. Still, the level observed in our urban children was almost two-fold the average level shown for US children (10-13 µg/l, (123)). A previous study, investigating children from another part of Managua (referents for a study of environmental exposure after the closure of a battery plant) also reported levels below 50 µg/l (118).

As discussed before, the gradient on lead soil content between the waste disposal site area and Acahualinca area supports the presence of the waste disposal site as a source of lead contamination. However, handling of car batteries may also be of concern for the Managuan population. The Ministry of Health of Nicaragua estimated that in Managua there are more than 300 small artesanal battery workshops currently working (Dr. Jesús Marín, Direction of Toxic Substances, Ministry of Health Nicaragua- personal communication). Most of them are operating without appropriate control (135). A recent study on soil leads level reported high lead levels at 10 artesanal battery workshop in Managua, up to 20,000 mg/kg soil, whereas soil samples from heavy traffic areas did not exceeded the EPA recommendation level (400 mg/kg soil) (136).

Organochlorine pesticides: Is there still an ongoing exposure to DDT/DDE?

As reported in previous studies from Nicaragua (73,74), 4,4’-DDE, was the most common compound identified in child workers and referents. Also, γ-HCH was found but at much lower levels. Even though the levels of 4,4’-DDT and 4,4’-DDE observed in our study group were not alarmingly high - much higher levels have been observed in agricultural regions elsewhere (76) (See also Table 1) - ongoing exposure to 4,4’-DDT in the Nicaraguan population should still be of concern. In Nicaragua DDT was banned in 1980 for agricultural purposes and the last legal application for vector control was reported in Nicaragua in 1991 (137), but there are recent reports showing a constant use of DDT by the people (138) and illegal trade of DDT coming
from contraband activities (137, 139). Thus, the magnitude of domestic and local DDT use in Nicaragua is still an open issue, and monitoring of exposure to already banned pesticides is still needed.

**Exposure to traditional POPs and emerging persistent organohalogen pollutants**

There are evidences that the levels of PCBs and some but not all POPs have been decreasing during the last decades in industrialized countries (119). Also, it has been suggested, mainly from data on mother’s milk, that PCB levels tend to be lower in the general population from slightly or not industrialized regions compared to highly industrialized areas (65, 140). However, we found that not only the children working at the waste disposal site, but also the referent children had higher levels of polychlorinated biphenyls than reported in children from industrialized developed countries (123, 124) (See also **Figure 4**). Much higher levels of PCBs are found in arctic and subarctic child populations (141). In the case of PCB, food generally accounts for the majority of the intake. In our study, fish consumption seems to contribute to the levels of PCBs in children, as expected. However, it also seems that the waste disposal area was a source of local contamination for PCBs. It is known that PCBs are still used as capacitor oils in Central America, and storage of obsolete stocks is not regulated (68). Our findings underline that there is a need to monitor human exposure to PCB and other “traditional” persistent organic pollutants in regions outside North America, Europe and the Arctic regions, to give guidance for actions to control the human exposure. Especially, time trend studies are urgently needed.

Monitoring of the “new” persistent organohalogen compounds has hitherto been focused almost entirely on North America, Europe, and some developed regions in Asia. There is a complete lack of human data from Central and Latin America, Africa and most parts of Asia. Moreover, data on children are still extremely scarce. Unexpectedly, the teenagers living and working on the waste disposal site had very high levels of low-medium brominated BDEs, higher by an order of magnitude than hitherto reported elsewhere. However, there is yet no human data on adverse health effects available for risk assessment. Also, quite unexpectedly, the levels of low-to medium brominated PBDE observed among referent children and young and middle aged urban women (paper III) were comparable to contemporary observations in USA (80, 142). Four of the teenagers in pool 1 had been living at the waste disposal site all their life. Thus, pre- and postnatal PBDE exposure (89) is also likely to
have occurred; taken the presumed long half life of low-medium brominated PBDEs into account (several years; (143)) this may partly contribute to their present levels. In contrast, the levels of BDE-209, which has a short half-life in serum (2 weeks; (144)), is likely to be dependent on current exposure only. The children in our study had higher levels of BDE-209 than Faroe children (141), and US and Swedish adults (142,144).

The need for integrated risk assessment
We have studied a vulnerable population of children and adolescents living in extreme socioeconomic conditions with multiple hazardous exposures. In order to enforce an appropriate risk assessment, not only risk assessment of compounds “one by one” but simultaneously should ideally be undertaken (145-147). Also, the need to investigate toxicological effect of chemical mixtures in regard to malnutrition in children has been recently claimed (148). The need for an integrated risk evaluation is even more evident as several of the substances that we have studied affect human reproduction. The exposure levels observed are directly relevant for risk assessment with regard to reproductive outcomes. Many of the teenage girls will be mothers in the near future; as many as 21% of adolescent females in Managua were mothers or pregnant in 2001 (149). However, such an integrated risk assessment is very difficult, due to the lack of knowledge of interactions.

Injuries – findings and implications
The proportion of child workers at the waste disposal site reporting any WRI is much higher than the estimated proportion for other child workers expressed in contemporary reports. Still our study most likely underestimates the true risk, as only presently active child workers were included.

The International Programme on the Elimination of Child Labour (IPEC/ILO) based on data from a large national survey in a developing country, confirmed that injury in child workers are of extremely concern due to the fact that 12% of all child workers have ever suffered a WRI during their working life (94). In Nicaragua a recent survey estimated that 14% of children working have suffered at least one WRI during the working life. In contrast, 48% of our child workers at the waste disposal site reported at least one WRI during the last 12 months and as many as 63% reported a WRI during the last 3 years. This is in line with findings from Guatemala, where 82% of children working at the main waste disposal in Guatemala City reported
that they had suffered open wounds and superficial injuries during their working life (13,150).

A prerequisite for prevention is the identification of characteristics of both the injuries and their circumstances of occurrence. The cluster analysis performed in our study opened the possibility to identify those groups of preventable injuries. An analysis of injury classes (typology) in relation with descriptor of the injury events, revealed that a great proportion (70%) of all injuries in child workers, point to a particular part of the body (lower/upper extremities) and specific types of injury (open wounds/superficial injuries), with low or moderate severity. These injuries occurred mostly during the moment when children were collecting and classifying the material. If these classes of injuries could be totally avoided, the absence from work and school would be reduced by more than 500 days per year in 100 workers. Simple protective measures can reduce the risk for injury, since today many of the children wear no shoes at all during their work, and no one has access to gloves.

The class of injury that includes the most severe injuries (class 4) reflects a very dangerous situation. In order to be able to have access to saleable garbage children have to risk their life. They wait for the municipal garbage trucks at the entrance of the waste disposal site, and jump onto the moving truck in order to collect the so called best material. Children that suffer this class of injury usually are absent from work and school for up to 2 months, which might cause the loss of the whole scholar year. Also, a long absence from work will have substantial impact on the family income, and thus also on the material situation for the child, as children working at the waste disposal site may contribute as much as 30% of the monthly family income (18,127). Our study in active workers underestimates the true risk in this situation, and it is obvious that also more serious accidents should be investigated.
Concluding remarks and issues for further research and actions

Our results confirmed and quantified hazardous factors related to the working condition of child workers at the waste disposal site. Quantitative data on the health effects from such extreme working situations as work at waste disposal sites has hitherto been scarce, or absent. Clearly, there is insufficient awareness of the high risk in this form of child labour, which may seriously endanger not only the physical, but also the emotional, intellectual and social development of the children.

Lead exposure is of major concern, and requires actions in order to reduce the impact on children’s health. There is a need of understanding about the exposure cycle to lead in the environment, not only at the waste disposal site but also in Managua in general. The exposure situation needs to be better characterized, and the sources of exposure identified. Presently available data from the general population are still scarce. Thus, representative population-based surveys are needed. Also, attention on the producer responsibility, i.e. the responsibility for production and handling process of lead within the life-cycle perspective, should be part of the considerations.

It is evident that there is an ongoing exposure to POPs and PBDEs. Even if the level of DDT/DDE and PCB, can be considered as not alarming, the differences observed between our study groups and findings from child populations in developed countries indicate that exposure to the traditional as well as the emerging organohalogen compounds is a current problem. Thus, we need to identify sources of exposure and vulnerable groups which might have a higher exposure than the general population. Moreover, the unexpected finding of high PBDE levels highlights that environmental and human exposure to potentially toxic chemicals should be investigated world-wide, not only in the developed countries. This is a responsibility for the scientific communities, international agencies as well as the national authorities.

In addition to the chemicals exposure, the conditions in which the work is carried out by the child workers exert an extremely negative impact on the child’s health status. Our study demonstrated that the overall injury risk in child workers at the waste disposal site was very high, as expected, with injuries directly related to work activities contributing the most. Even if it can
be agreed that child labour at waste disposal sites is a serious violation of all national and international commitments concerning the human rights of children, and that such work should be abolished, in a short perspective it is also necessary to face the question if there are feasible strategies for injury prevention. A considerable proportion of the injuries are likely to be avoided by applying simple protective measures. The risk for the most severe injuries can be reduced by focusing on those elements that can be controlled, such as traffic inside the waste disposal area and garbage deposition.

Our experience shows that epidemiological studies can be done with relatively small financial resources in a population living under extreme conditions. A dedicated support from the local communities and institutions is necessary to guarantee an interactive communication with the population before, during, and after the study.

**Funding**

The studies included in this thesis were funded by the Swedish International Agency for Research Cooperation with Developing countries, SAREC, within the frame of a multidisciplinary co-operation program between Lund University and the National Autonomous University of Nicaragua (UNAN-Managua). Field works and logistical preparation were supported by the “Centro de Promoción de la Juventud y la Infancia Dos Generaciones: Programa Comunitario Acahualinca”, Nicaragua.
Acknowledgements

First of all, I want to thank all children and parents who participated in our studies. Thanks for everything I learned from you. You transformed my scientific research training from an academic experience to an experience of life.

Professor Kristina, I have no word to express my gratitude to you. From the very beginning you have been not just a supervisor, but a friend. Thank for being an extraordinary teacher, sharing your scientific knowledge, your personal values, your principles, especially your time. So many times and for so long hours. Thanks for reminding me what “being a researcher in Nicaragua” means. Also, thanks to your family, Per, Eskil, Tor, Anna and Valdemar. Thanks for letting me enjoy so many marvellous moments around you, and teaching me new and interesting things.

I want to thank Professor Lars Hagmar for his support and for being an example to all of us, as person and scientist as well.

I want to thank Professor Mario Jiménez, Dr. Gustavo Sequeira and Danilo Hernández. Thanks for making all this work possible and for promoting the development of our Faculty. Your support to my work has been invaluable.

At the same time I want to thank the Multidisciplinary Environmental Research Program (PMIA-UNAN Managua) coordinated by Ing. Dionisio Rodríguez, for supporting these research projects.

I want to thank “Centro Dos Generaciones” and “Chateles Project” for all their support to this research. Most of the success belongs to them. Especially I want to thank Lic. Mario Chamorro and Lic. Jacqueline Vargas from Dos Generaciones, and Linda Núñez from Chateles Project. They encouraged us and gave us all the logistical support that was needed. The work they did made this research feasible.

I want to express my enormous gratitude to all of you who have made this thesis possible in one way or another (usually in many several ways):
In Sweden

Professor Maria Albin, thank for your commitment and enthusiasm about our program. Thanks for encouraging us to continue and for sharing your constructive and critical mind with me. But also I want to thank you for being patience and kind, even when I engaged you and Kristina in an unexpected 15 hour boat trip in the middle of the night over the Lake of Nicaragua, because of a small problem with some not updated websites.

My co-supervisors here in Lund Jan-Eric Karlsson, Anna Axmon and Thomas Lund. Thank for you knowledge, support, friendship, and time whenever I had a question.

Giovanni Ferrari and Anna Akantis, thanks for skilful chemical analyses of metals in blood. Thanks also to Tommy Olsson from the Division of Plant Ecology and Systematics, for helping with the soil analyses.

Especially thanks to Lisbeth Prahl and Ralf Rittner. I can not remember how many times I ask for your help…everyday. Thanks for always being there.

The staff from the section of epidemiology. Thank for building a really nice environment to work. All of you have made me feel really comfortable in this country, sharing chats, laughs, knowledge and helps when I needed.

The staff from the Department of Environmental Chemistry, Stockholm University, especially to my co-authors Linda Linderholm, Emma Fäldt, Professor Åke Bergman and my co-supervisor Maria Athanasiadou, not only for their support with the chemical analysis and valuables comment to my manuscripts, but for their great commitment to this project and for being so kind to me, all times I visited the department. Maria thanks for your lovely support, I am really grateful.

Especial thanks to Anna Oudin and Emilie Stroh. Your friendship, enthusiasms, and kindness have made my time in Sweden far more enjoyable. It was great to meet you during those wine evenings in Florence.

Kjell Andersson, to do everything possible to teach me diving. I hope you will succeed one day.

A Lucas, Corina y Diego, por ser la familia Latino Americana que tanto me hace recordar el calor de nuestros suelos. Gracias por su ejemplo y alegría.
Quiero agradecer a todos mis compañeros estudiantes del PMIA: Marvin, Rainer, Danilo, Luis, Martha, Katia, Marlene, Alfredo, Francisco y Martín. Gracias por el apoyo, consejos y ánimo que hemos compartido durante esta etapa, a veces dura y otras veces más dura. En especial quiero agradecer a Marvin su amistad y apoyo, y por siempre aconsejarme para bien en mi trabajo.

In Nicaragua:

Quiero agradecer a toda mi familia por todo el apoyo, el amor y la paciencia que me han tenido a lo largo de estos años de estudio. Sobretodo, quiero agradecer a mis hermanos Néstor y Tavo, que junto a mi madre, se desvelaron conmigo tantas noches etiquetando muestras, paquetes y metiendo datos en la computadora. Sin ellos el trabajo de campo habría sido prácticamente imposible.

Quiero agradecer especialmente a Adolfo Salinas. Vos has sido mi compañero, amigo, organizador, ejecutor, etc., en todas y cada una de las tareas que he tenido que realizar desde que ingresé a la facultad de medicina. Sin vos, menos de la mitad se habría podido hacer. Gracias por hacer todo con tanto entusiasmo y compromiso, inclusive muchísimo mejor que yo. Es más, mi familia llama por teléfono a la facultad y ya no preguntan por mi, si no por vos.

En esta oportunidad quiero agradecer y recordar a aquellos que en este momento no están cerca de mi, pero que confiaron en mi y en mi trabajo, y que me han enseñado que lo importante es “en todo amar y servir”; Hermana Pilar Crespo, Padre Chicho y Padre Fernando Cardenal. También quiero hacer presente al Padre Javier Yasera y mi tía Emperatriz. Dos formas distintas de enseñarme y darme amor.

Quiero agradecer a Rosita, por hacerme pisar siempre la tierra con mucho amor y paciencia, y por recordarme que hay que “esperar contra toda esperanza”. A mis amigos Gustavo, Rodrigo, Erick, Juan Carlos, Hugo, Bautista, Benjamín, Ronald, Elías, Ocón, Valeria y Daisy Bravo, Cecilia, gracias, por hacer de mis estadías en Nicaragua momentos inolvidables. Ustedes han sido una gran inspiración en mi vida.
Quiero agradecer a Juan Carlos Ampié y Gray Gutiérrez Cheng, grandes amigos que tuvieron la paciencia de ayudarme con el inglés. Difícil tarea la que aceptaron hacer.

Quiero agradecer a todos, absolutamente a todos mis profesores del Departamento de Medicina Preventiva de la Facultad de Medicina en Nicaragua. Gracias por todo el apoyo y la confianza que me han brindado. Ustedes son y serán siempre mis maestros.

Quiero agradecer a todo el personal de administración de la Facultad de Medicina. En especial a doña Patricia, Karlita, y nuevamente Adolfo. Gracias por hacer siempre lo posible y hasta lo imposible por ayudarme en mi trabajo, y perdonen por todas las carreras que siempre le hacía pegar.

También quiero agradecer a los conductores, Don Salvador y Don Wilfredo, por toda la paciencia que siempre han tenido, y perdonen por las interminables jornadas de trabajo durante las salidas de campo, que muchas veces se prolongaban hasta altas horas de la noche, bajo la lluvia.

Gracias a todos los que participaron en los trabajos de campo: Martha, Eddy, Keyla, Iris y Yelda (trabajadores del Centro Dos Generaciones), Sumaya, Denis Pupiro y Martín del Carmen Villalta (técnicos y asistentes en el trabajo de campo). Gracias por su esfuerzo y disposición.

Quiero agradecer de forma especial a todo el grupo de estudiantes que ha trabajado conmigo desde que comencé en este programa. Gracias por el apoyo y todo lo que aprendí de ustedes.

En general, quiero agradecer a las actuales autoridades de la Facultad de Medicina, por todo el apoyo que nos han brindado, y por tratar de garantizar que siempre, en la medida de lo posible, contáramos con todo aquello que requeríamos para nuestro trabajo.
Populärvetenskaplig sammanfattning

Omkring 600 barn och tonåringar arbetar på Managuas stora soptipp, den största i Nicaragua. De samlar och sorterar avfall på den öppna tippen, som täcker ett 7 km² stort område i stadens utkant vid stranden av Managuasjön. Sådant arbete, som förekommer i många stora städer i utvecklingsländer, anses vara ett av de mest riskfyllda typerna av barnarbete som finns. Ändå är kunskapen om sådant arbete och dess risker bristfällig.

Vi har undersökt kemisk exponering och risk för skador bland 103 barnarbetare i åldrarna 6 till 15 år från Managuas soptipp. Nästan hälften av barnen bodde också på själva soptippsområdet, medan de övriga bodde i ett närliggande område, Acahualinca. För jämförelse studerades också 102 barn från Acahualinca och 34 barn från centrala Managua, 10 km längre bort, som inte arbetade på soptippen. Detta gav möjlighet att också studera omgivningsexponeringen från soptippen. Barnen intervjuades om levnadsförhållanden, arbetsförhållanden och om alla inträffade skador på arbetsplatser, i skola och i hemmet under de senaste 12 månaderna. De fick lämna blodprov för undersökning av halterna av bland annat de toxiska metallerna bly, kvicksilver och kadmium, och långlivade organiska miljögifter som bekämpningsmedel och PCB. Vi undersökte också halterna av ett relativt nytt organiskt miljögift, det bromerade flamskyddsmedlet PBDE. I ett senare skede insamlades också jordprover från soptippsområdet och från Acahualinca för undersökning av metallinnehåll.

Barnen som arbetade på soptippen hade högre halter av bly, kvicksilver och kadmium än barnen i jämförelsegrupperna. En tredjedel hade högre blodblyhalter än 100 µg/l, en nivå där åtgärder för att minska exponeringen klart rekommenderas. Vi fann också att barnen i det närliggande bostadsområdet hade högre blyhalter än barnen från centrala Managua. Även om kvicksilverhalterna var högre bland barnarbetarna, var nivåerna inte sådana att de kan anses innebära någon hälsorisk. Konsumtion av fisk från Managuasjön påverkade kvicksilverhalterna endast obetydligt.

Halterna av flera av de organiska miljögifterna, särskilt PCB, var också högre bland barnarbetarna än i jämförelsegrupperna. Vi vet att PCB, som sedan länge varit förbjudet i västvärlden, fortfarande används i Centralamerika, eller lagras under okontrollerade former. Också barnen i jämförelsegrupperna hade klart högre halter av en nedbrytningsprodukt av bekämpningsmedlet DDT och av PCB än barn i USA och Västeuropa. Halterna av dessa ämnen är i
stadigt minskande i västvärlden. Man har ytterligt begränsad kunskap om hur utvecklingen över tid ser ut i Central- och Latinamerika, eftersom alltför få undersökningar har gjorts. Helt oväntat fann vi extremt höga halter av PBDE bland barnen som bor och arbetar på soptippen, högre än vad som tidigare har rapporterats. Också barnen i jämförelsegrupperna hade oväntat höga halter av dessa ämnen. Detta är den första undersökningen av människors PBDE-halter i Central- och Latinamerika, och fynden visar tydligt att det är ytterligt angeläget att studera spridningen av de nya miljögifterna även i icke-industrialiserade länder och bland särskilt utsatta grupper.


I våra studier har vi velat mäta exponeringsnivåer och kvantifiera risker för att tydliggöra barnarbetarnas situation, i förhoppning om att ökad kunskap och medvetenhet på sikt kan bidra till förändring. Vi har också fått värdefull kunskap om halterna av flera vanliga miljögifter bland helt vanliga fattiga storstadsbarn i ett u-land. Detta är något som hittills varit alltför bristfälligt undersökt.
Resumen en español
Trabajo infantil y consecuencias en la salud:

Exposición a químicos peligrosos y lesiones relacionadas con el trabajo, en niños y niñas que trabajan en el basurero Municipal de Managua, La Chureca.

Mas de mil personas, entre ellas aproximadamente 600 niños y niñas menores de 18 años, trabajan recolectando desechos el basurero municipal de Managua, Nicaragua. Este basurero, el más grande del país, está localizado a orillas de lago Xolotlán. El trabajo que los niños y niñas realizan en el basurero es considerado como una de las peores formas de trabajo infantil.

Esta tesis pretende describir algunos de los peligros para la salud que los niños y niñas que trabajan en los sitios de depósito de basura enfrentan día a día, como la exposición a químicos peligros y las lesiones ocupacionales. Esta tesis está basada en una serie de estudios que tenían por objetivos: 1) estimar los niveles de exposición a ciertos químicos que han sido relacionados con efectos negativos; entre ellos se investigaron metales pesados como el plomo y el mercurio, compuestos orgánicos persistentes como plaguicidas organoclorados y compuestos difenílicos policlorados (PCB), químicos industriales cuyo uso ha sido prohibido, y por último se investigaron los retardantes de flama éteres difenílicos polibrominados (PBDE), estos últimos se usan actualmente en el mundo para evitar que los objetos se incendien fácilmente; 2) describir la ocurrencia de las lesiones relacionadas con el trabajo e identificar las características más comunes de estas lesiones, así como ciertos factores que podrían ser prevenibles con el objetivo de reducir el impacto de estas lesiones sobre el estado de salud de los niños y niñas.

Esta investigación se desarrolló con la colaboración del Centro Dos Generaciones, un organismo no gubernamental especializado en temas de la niñez y la adolescencia, que ha estado trabajando con las familias que habitan alrededor y dentro del basurero desde 1992, con una perspectiva especial orientada a la erradicación de una de las peores formas de trabajo infantil, desarrollando diversos programas que atienden a los niños que trabajan en la recolección, clasificación y comercialización de desechos.

Se entrevistaron a 103 niños trabajadores del basurero, 102 niños no trabajadores que viven en el barrio aledaño, Acahualinca, y 34 niños de un área alejada del basurero, con edades comprendidas entre los 6 y 15 años. Se obtuvieron muestras sanguíneas para determinar las concentraciones de
metales pesados y compuestos orgánicos persistentes. Adicionalmente, se aplicó un cuestionario sobre lesiones sufridas durante los últimos 12 meses que causaron al menos un día de ausencia del trabajo/escuela.

En todos los niños y niñas investigados se detectó la presencia de múltiples químicos, entre ellos los más abundantes fueron plomo, DDT, PCB y PBDE. Es importante señalar que esta es la primera vez que se reportan datos de PCB en niños y niñas procedentes de Latinoamérica, y es la primera vez que se reportan niveles de PBDE en poblaciones humanas de Centro y Sur América.

El compuesto de mayor preocupación es el plomo, debido a que una tercera parte de los niños y niñas investigados excedieron el nivel de plomo sanguíneo de 10 µg/dl (nivel de acción recomendado por el CDC-Atlanta). Inclusive, casi el 50 % presentó niveles de plomo por encima de 5 µg/dl. Algunos estudios han reportado efectos en la salud, aún a niveles tan bajos como éstos. Un ejemplo de posibles efectos es la presencia de leves alteraciones del proceso de aprendizaje del niño. En general, la exposición a plomo en los niños es un ampliamente reconocido riesgo para la salud. El desarrollo del sistema nervioso central es especialmente sensible a la exposición al plomo. Alteraciones del desarrollo mental han sido asociadas con la exposición a plomo en diversos estudios epidemiológicos. Se ha documentado que el plomo puede ocasionar daño en concentraciones bajas (entre 5-6 µg/dl) y que los niños son más sensibles que los adultos a sus efectos. Es indiscutible que la exposición a plomo en los niños y niñas trabajadores es un problema de salud pública.

En general, para el resto de los compuestos, los niveles no fueron alarmantes, encontrándose por debajo de los niveles a los que se han observado efectos sobre la salud. Sin embargo, los niveles encontrados en los niños y niñas trabajadores fueron muchos mayores que los niveles reportados en niños de países desarrollados como Alemania y Estados Unidos. Es decir que algunos grupos de nuestra población siguen expuestos a sustancias cuyo uso fue restringido en el pasado. Nuestro estudio sugiere que el basurero municipal es una fuente de exposición a plomo, DDT, PCBs y PBDEs ya que los niños que trabajan y viven dentro del basurero presentan niveles más altos que los niños no trabajadores que viven en el barrio aledaño y muchísimo más altos que los niveles de los niños que viven en zonas alejadas del basurero.

En relación al DDT, este plaguicida fue ampliamente usado en campañas para el control del mosquito que transmite la malaria. Además existen reportes que reflejan que el DDT se sigue comercializando entre la población de forma no
controlada. Por tal motivo, la exposición a DDT podría seguir representando un problema actual.

Es evidente la existencia de una compleja exposición a químicos considerados peligrosos. El riesgo de efectos en la salud no es solo para la presente generación, sino para la futura, ya que es probable que muchas de estas niñas se conviertan en madre muy pronto. En nuestro estudio, cerca del 50 por ciento eran niñas u adolescentes mujeres. La prevalencia de embarazos en la adolescencia en Nicaragua es alta. En el año 2001 el 21 % de las adolescentes de Managua, ya eran madres o estaban embarazadas. Esta situación demanda medidas urgentes de protección y monitoreo.

En relación a la ocurrencia de lesiones, se observó que 66 niños trabajadores y 20 niños no trabajadores reportaron al menos una lesión durante los últimos 12 meses (los niños trabajadores del basurero presentaron un riesgo de sufrir lesiones de cualquier tipo 7 veces mayor que los niños que no trabajan en el basurero). Muchos de los niños trabajadores reportaron más de una lesión durante el mismo año. La frecuencia de lesiones relacionadas con el trabajo en los niños trabajadores fue alta, de 2.2 por 1000 persona-día, en otras palabras, cada semana uno de cada 100 niños sufre una lesión que ocasiona pérdida de clases o ausencia del trabajo por al menos un día. Heridas abiertas que afectaron extremidades inferiores, causando entre 4-13 días de ausencia del trabajo/escuela (34 %) representan la “clase” más común de lesiones ocupacionales reportada por los niños trabajadores. También se reportaron traumas severos (11 %), relacionados principalmente con atropellamiento. Un 9 % de las lesiones ocupacionales resultaron en deterioro funcional o dolor persistente, 0.07 por año-de-trabajo.

Nuestro estudio subestima el riesgo y la severidad de las lesiones ocupacionales en los niños y niñas trabajadores debido a que se investigó únicamente niños y niñas que se encontraban trabajando en el basurero al momento del estudio, y que además estuviesen viviendo con sus familias. Es decir que probablemente, hay niños y niñas que no estaban trabajando en ese momento debido a accidentes o lesiones severos que no les permitió continuar trabajando en el basurero, por los cual nuestro estudio no detectó este tipo de lesiones. Por otro lado, niños y niñas que no laboran de forma regular debido a diversas razones, como por ejemplo a que no cuentan con una familia, o a que consumen algún tipo de droga, probablemente desarrollan ciertas actividades o comportamientos que los colocan en mayor riesgo de sufrir lesiones severas.
En resumen, nuestro estudio confirma y cuantifica la presencia de factores de riesgo para la salud relacionados con las condiciones de trabajo de los niños que laboran en el basurero municipal de Managua. Es evidente que las condiciones en que los niños y niñas desarrollan su trabajo en el basurero pueden producir un considerable impacto negativo sobre la salud de estos niños y niñas. Este tipo de trabajo es considerado como una de las peores formas de trabajo infantil. Es cierto que se deben realizar esfuerzos para que en mediano y largo plazo este tipo de trabajo sea erradicado. Sin embargo, nuestro estudio indica que se requiere la implementación de medidas a corto plazo que reduzcan el impacto negativo de las condiciones que los niños y niñas enfrentan ahora mismo. Un hallazgo importante es que la gran mayoría (cerca del 70 %) de lesiones relacionadas con el trabajo se pueden prevenir con sólo la implementación de simples medidas de protección personal (uso de guantes o zapatos adecuados). Igualmente las lesiones más severas se podrían prevenir a través de sencillos sistemas de regulación de la entrada de los camiones y del depósito de la basura. En cuanto al riesgo de exposición a múltiples químicos peligrosos, especial atención se debe poner en la identificación de las fuentes de plomo y en la búsqueda de estrategias para la protección de los grupos sensibles, como lo son las adolescentes trabajadoras y los niños y niñas que comienzan a trabajar a muy temprana edad, inclusive antes de los 6 años.
References


8  Scanlon TJ, Prior V, Lamarao MLN, Lynch MA, Scanlon F. Child labour BMJ 2002;325:401-03.


17 ILO-IPEC. [Base line study. Child labour at the San Pedro waste disposal site, Honduras] [In Spanish]. San José, Costa Rica: International Labour Office (ILO), International Programme on the Elimination of Child Labour (IPEC); 2004. Available from
18 IDESO/UCA. [Base line study: Program on progressive elimination of child labour at Managua city dump ‘La Chureca’] [In Spanish]. Managua: Instituto de Encuestas y Sondeos de Opinión-Universidad Centro Americana (IDESO/UCA); 2001.


77 Yanez L, Ortiz-Perez D, Batres LE, Borja-Aburto VH, Diaz-Barriga F. Levels of Dichlorodiphenyltrichloroethane and Deltamethrin in Humans and Environmental Samples in Malarious Areas of Mexico. *Environmental Research* 2002;88:174-81.


85 Jones-Otazo HA, Clarke JP, Diamond ML, Archbold JA, Ferguson G, Harner T, Richardson GM, Ryan JJ, Wilford B. Is house dust the...


97 Vargas J. Register of child workers at the municipal waste disposal site, La Chureca] [In Spanish]. Managua: Centro de Promoción de la Juventud y la Infancia “Dos Generaciones”: Programa Comunitario Acahualinca; 2002.


105 Fäldt E. Analysis of polybrominated diphenyl ethers (PBDEs) and hydroxylated PBDEs in serum from children living at a city dump in Managua and in women with intake of lake Managua fish [Diploma work 20p]. Stockholm: Stockholm University; 2005.


120 Longnecker MP, Rogan WJ, Lucier G. The human health effects of DDT (dichlorodiphenyltrichloroethane) and PCBs (polychlorinated biphenyls) and an overview of organochlorines in public health. Annual Review of Public Health 1997;18:211-44.


127 Borge & Asociados. [Diagnostic study on generation of alternative or complementary incomes, opportunities, and potentialities of and for children from Acahualinca] [In Spanish]. Managua: Centro Nicaraguan de Promoción de la Juvenrud y La Infancia “Dos Generaciones”; 2000.


133 Pastoral Penitenciaria / MINSA. [Child Labour and Health: Children working at the city dump "La Chureca"] [In Spanish]. Managua: Pastoral penitenciaria / Ministry of Health, Republic of Nicaragua; 2003.


135 Lozano M. [Inventory of lead artesanal workshops in Managua] [In Spanish]. *Boletín Epidemiológico* 2002;No. 19:23.

136 Valverde G, Castro G. [Evaluation of lead levels in soil samples from artesanal battery workshops from districts I, II and III in Managua] [In Spanish]. In: III Reunión Científica de Docentes Investigadores; 2005; Managua, Nicaragua: Universidad Nacional Agraria (UNA).


HEAVY METAL EXPOSURE IN CHILDREN WORKING AT A
WASTE DISPOSAL SITE, AND IN REFERENT CHILDREN FROM
MANAGUA, NICARAGUA

Steven N. Cuadra 1,2, Jan-Eric Karlsson 2, Thomas Lundh 2, Kristina Jakobsson 2

1 Faculty of Medicine, Universidad Nacional Autónoma de Nicaragua, UNAN-Managua, Nicaragua
2 Department of Occupational and Environmental Medicine, Lund University Hospital,
SE-221 85 Lund, Sweden

Correspondence:
Steven N. Cuadra, Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden.
Telephone: +46-46 17 7288. Fax: +46-46 17 36 69. E-mail: steven.cuadra@med.lu.se

Key words: Lead, mercury, selenium, children, waste disposal site, Nicaragua
INTRODUCTION

Recently, concern has risen in the Central American region, regarding one of the worst forms of child labour: scavenging at dumpsites (1-5). Hazardous factors include the environmental conditions in which the work is carried out, the exposure to multiple environmental contaminants, and the many social problems related to human survival in places where garbage is deposited (6). It is estimated that there are thousands of children and adults working at several waste disposal sites in the region (7).

Among the environmental contaminants encountered at dump sites, lead is of special concern (8). Also, a potential risk of exposure to other toxic heavy metals like mercury and cadmium is present (8-11). Childhood lead exposure constitutes a well-recognized environmental hazard (12-14). The developing central nervous system is especially sensitive, and impairment of mental development has been associated with lead exposure, without evidence of any threshold level (12, 15, 16). Not only fetal and infant exposure, but also exposure later during childhood may affect cognitive development (15). The 1991 Centers for Disease Control (CDC) statement on childhood lead poisoning set 100 $\mu$g/l as a screening action guideline, and a management tool on community level (17, 18); it does not imply that levels below are “safe”. Recent data suggest cognitive effects (19) below this level, and subtle neurodevelopmental effects (16) have been reported at fetal exposure levels as low as 50-60 $\mu$g/l. The central nervous system is also the critical organ for mercury (20-22). For cadmium, renal toxicity is the critical effect (23). The essential trace element selenium may alleviate toxic effects of mercury and cadmium (24, 25). The geographical variation in selenium is well known; however human data from Central America is yet entirely lacking (25, 26).

Managua, the capital of Nicaragua, is situated at the shore of Lake Xolotlán. The municipal domestic and industrial waste disposal site in Managua, “La Chureca”, located on the south shore of Lake Xolotlán, is the largest dump of Nicaragua. This dump covers an area of 7 km². Approximately 1000 persons, of whom more than 50% are children under age 18, work at the waste disposal site. Also more than 115 families are living inside the dump (27, 28). Recollection, classification, selling, storing, and cleaning of recyclable waste are the
most common activities. Children usually are involved in more than one activity, most frequently handling glass, metals, and plastic. Often, the material is stored at home. Also, recollection of food from the waste disposal site for self-consumption is reported. A thick cloud of smoke covers the area as the waste is burned to retrieve iron and other materials. The waste is not compressed, the sun is intense, and a constant breeze from the lake sweeps the area. Thus, substantial amounts of airborne dust are generated.

The lake Xolotlán, which is the second largest lake of Nicaragua, has been used as the recipient of domestic and industrial wastewater from the city, and receives the superficial run-off from its drainage basin, which is being intensively cultivated. Its contamination has been well documented (29). Mercury has been detected in water, sediment and fish from Lake Xolotlán and in human population from communities located at the lakeshore (29). Fish from Lake Xolotlán is an important part of the diet, not only for the population in rural fishing villages around the lake, but also for segments of the Managuan population.

The chemical exposure situation at the waste disposal site is complex. The aim of the present study was to assess the levels of lead (Pb), mercury (Hg), cadmium (Cd), and selenium (Se) in blood in children working and sometimes also living at the waste disposal site. Also, appropriate reference populations were investigated. Soil samples were analyzed for lead and other metals. The influence of dietary exposure to mercury was further evaluated by assessing Hg levels in blood from young women that were high consumers of fish from the lake Xolotlán, and referents with no fish consumption. The present study is part of a larger research project that includes exposure to persistent organohalogen compounds as polychlorinated biphenyls (30) and polybrominated diphenyl ethers (31), and exposure to air contaminants for child workers at the waste disposal site. Also, respiratory health and injury risks are investigated.

SUBJECTS AND METHODS

Study population
The children study and reference groups were established with the help of local non-governmental organization working in child labour eradication programs, “Centro Dos
Generaciones” and the “Chateles” project. Dos Generaciones attended children under age 18 that regularly work at the waste disposal site and have a family (N=438), through its community program. By using Dos Generaciones register, all current child workers were identified who: a) had worked at the waste disposal site, La Chureca, for at least one year, and b) were of age 6-15 years, and c) lived inside La Chureca, or in a neighbourhood nearby, Acahualinca (N=117). The participation rate was high, 87% (n=103), There were 61 children living inside La Chureca and 42 children living in the Acahualinca area. For description of socioeconomic characteristics, see Table 1.

By consulting the student register at the local public primary school and with the help of Centro Dos Generaciones, a list was elaborated of all children aged 6-15 year, presently attending the local primary school, living in Acahualinca, and never having worked at the waste disposal site (N=150). All children were invited. The participation rate was 67% (N=102), for children in the reference group from Acahualinca. Another 34 children not working at the dump and living between 10-20 km away from the dump in the south and central areas of Managua were recruited by help from the Chateles project. All invited children from the Chateles project participated.

We divided the participating children in five groups: Group #1: 42 children living at the waste disposal site, having worked there for 4 years or more, and eating fish from the lake Xolotlán, Group #2: 61 children living in the near-by area, Acahualinca, having worked at the waste disposal site for 4 years or more, and eating fish from the lake, Group #3: 59 children not working at the waste disposal site, living in Acahualinca, eating fish from the lake, Group #4: 43 children not working at the waste disposal site, living in Acahualinca, and not eating fish from the lake and Group #5:34 children living in a remote urban area and not eating fish from the lake. For description of sociodemographic characteristics of the five study groups of children, see Table 1.

Additionally, to explore the influence of consumption of fish from Lake Xolotlán we enrolled 6 women aged 15-17, living in fishermen’s families in San Francisco Libre, a fishing village on the rural north-east side of the lake, and 5 women aged 15-23 from another fishing village, Mateare, on the south-west shore of the lake, 25 km from the city.
of Managua (Figure 1). These young women with high fish consumption were identified by the local health centers. The subjects ate as a median 8 (range 4-16) fish meals/week. We also recruited 4 women from urban Managua, aged 18-25 and living in similar poor socio-economic conditions, who never ate fish.

The field work was carried out in June and July 2002. The Ethic’s committees at Lund University and The National Autonomous University of Nicaragua (UNAN Managua) approved the study protocol, and a written informed consent was obtained from the participants and guardians.

**Interview**
Trained staff personally interviewed study participants following a structured questionnaire, at “Centro Dos Generaciones” local office, requiring help from children’s parents when children were younger than 10 years old. Otherwise children attended the interview in private. Detailed information on demographic characteristics, common daily activities, material handling, and waste disposal site work history (age of onset of work, years worked, current working hours per day and working days per week, present and previous working site, type of activities at the dump and other types of work activities elsewhere), was collected. Also, information on duration of dwelling and basic housing conditions such as water and electricity was obtained. Dietary habits, especially fish consumption, were assessed. We also asked about present and previous contact with car batteries at work, at home and or in the residential area. A similar interview protocol was used also for the young women.

**Blood sampling**
From all participants 5 ml of blood was drawn from the cubital vein into evacuated sodium heparine tubes (Vacutainer, Rutherford NJ). The tubes were stored in refrigerators, and sent by overnight carrier to Sweden for analysis.

**Soil sampling**
Exploratory soil samplings at the waste disposal site La Chureca and the nearby residential area Acahualinca were performed in February 2004 to investigate potential point emissions
sources of lead, and diffuse lead contamination. We collected composite soil samples from 16 places at the waste disposal site: eleven homes, one playground at the local school, one from the recollected waste dealer area, two samples along the main road in La Chureca and one from a public soccer field. From the Acahualinca area there were 17 composite samples: from eleven homes, one playground at the local school, two from public parks, one from the public soccer field, and two from other public areas.

The sampling strategy was in accordance with recommendations by USA Technical Review Workgroup for Lead (32). This technique is also adopted by the U.S. Environmental Protection Agency (33, 34). Sampling procedures depended upon the size and shape of the object of interest. For a building (home) one composite soil sample was collected, consisting of between 5 and 10 aliquots from the house perimeter from all sides where bare soil was present. Each spot was at least 2 feet distant from each other and 2 feet away from the foundation. For non-linear open areas (e.g. play grounds or soccer fields) the composite sample consisted of 5 to 10 aliquots collected along an X-shaped grid with each spot located at least 5 foot from each other. A line pattern was used when the area was linear (e.g. a road) and the aliquot samples were collected at 5 feet intervals. Prior to sampling large non-representative debris including rocks, pebbles, leaves and roots were removed from the soil surface. The soil samples were collected by pushing a coring tool into the ground about 1 inch deep. The tool was moved gently from side to side to loosen a plug of soil. The top one half inch of the sample was then cut from the core with a stainless steel knife and transferred to a zip lock plastic bag which then was used for the entire composite sample. The core sampler was cleaned with a disposable wipe between each composite sample.

Chemical analysis

Blood samples

The concentration of Pb, Cd, Se and Fe was determined by inductively coupled plasma-mass spectrometry (Thermo X7, Thermo Elemental, Winsford, UK). The samples were prepared according to Bárány et al (35). The limit of detection, calculated as three times the standard deviation (SD) for the blank were for Cd 0.02 μg/L, Pb 0.18 μg/L, Se 2.0 μg/L and Fe 254 μg/L. The analytical accuracy was checked against reference material.
(Seronorm; batch OK0336, Nycomed, Oslo, Norway). The results obtained were for Cd 0.65±0.04 µg/L (mean±SD) vs. recommended 0.70 µg/L, Pb 31±0.89 µg/L vs. 33 µg/L, Se 78±7.4 µg/L vs. 80 µg/L, and Fe 436±47 mg/L vs. 435 mg/L. The determination of Hg was made in acid-digested samples by cold vapour atomic fluorescence spectrometry (36). The limit of detection was 0.23 µg/L and the result obtained from the reference material was 2.0±0.27 µg/L vs. recommended 2.0 µg/L.

Soil samples
Incidental ingestion is the major pathway of exposure to metals in soil and dust. This is best represented by the metal concentration in the particle size fraction that sticks to hands, clothing, and other subjects that may be mouthed, i.e. the fine fraction, consisting of particles smaller than 250 µm. For that reason each composite soil sample was passed through a 250 µm sieve. The fine fraction was collected and the metal content analysed by Induced Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The analyses were performed at the Department of Plant Ecology and Systematics at Lund University.

Statistics
For testing of group differences, the Mann-Whitney U-test and ANOVA Test were used. The influence of age, duration of work at the waste disposal site, and sex on blood metal levels was also explored in uni- and multivariate linear regression models. The influence of fish consumption on B-Hg levels was assessed by multiple linear regression, with sex, age and waste disposal site work explored as covariates. We used the change-in-estimate-method suggested by Greenland (37), and kept potential covariates in the model only if the effect estimate was altered by more than 10%. Blood lead levels are related to the hemoglobin (B-Hb) content (15, 38, 39). We used B-Fe as a surrogate for B-Hb, and repeated all analyses using instead the B-Pb/B-Fe ratio. The findings did not change. Thus, we report only unadjusted B-Pb levels.

Statistical significance was defined as a \( p \)-value less than 0.05.
RESULTS

The children working at the waste disposal site had higher levels of B-Pb, B-Hg, and B-Cd compared with the non-working referents groups (Table 2). No differences were observed between children who both worked and lived at the dump, and those who just worked at the dump and lived in Acahualinca. There was also a clear gradient for B-Pb, but not for B-Hg and B-Cd, between non-working children from Acahualinca, and those from the remote urban area. B-Se levels did not differ between groups. Multivariate modeling confirmed the findings in the group comparisons.

Among waste disposal site child workers (group 1+2) as many as 28% had B-Pb higher than the community action level 100 µg/l recommended by CDC (Table 3). In contrast, only 2 % among children not working living in the nearby residential area Acahualinca and no one from the remote urban area exceeded this level. However, it should be noted that as many as one third of the non-working children in Acahualinca had levels above 50 µg/L. In all study groups, boys had 30-40% higher B-Pb levels than girls (Figure 2). Age had no significant influence. Neither the duration of work at the waste disposal site nor any reported history of contact with car batteries were related to the levels of lead in the children.

The highest concentrations of lead in soil were found in three homes in the Acahualinca neighborhood where car battery handling was supposed to have occurred presently or in the past (Table 4). Excluding these homes, the lead content in soil at homes at the waste disposal site was higher than the lead content in soil in Acahualinca homes, however not reaching statistical significance. Similarly, the common areas at the waste disposal site were indicated to have higher soil Pb levels than in Acahualinca, whereas the lead content in soil from the playground at school did not differ between areas.

As expected, consumption of fish from Lake Xolotlán influenced the B-Hg levels in young women as well as in children not working on the waste disposal site (Table 2). Among young women, those consuming median 8 fish meals per months had fivefold B-Hg-levels compared to women never eating fish. Also, as expected, there was a clear gradient in Se
between young women with high or no fish consumption. The additional effect of one fish meal from the lake per month was estimated to be 0.2 (95% CI 0.1-0.3) µg/L. The effect estimate was similar, whether it was calculated from data from young women or from children.

DISCUSSION

This study suggests an occupational and environmental exposure to heavy metals such as lead and mercury in children working at the waste disposal site. Especially, the lead exposure is of major concern, since among these children 28 % had B-Pb above 100 µg/l (the CDC’s recommended action level for lead) (17, 18). Another study performed in child workers from La Chureca reported levels of lead that were similar to the level found in our study, with 25 % of all children having higher level than 100 µg/l(40). Thus, a good part of the child workers are exposed to lead at levels where subtle developmental and cognitive effects have been observed (15, 16, 19, 41)

The waste disposal site workers included in the study represent the great majority of all child workers living with a family in the selected age category. They were compared with referents living in an area nearby the waste disposal site and with referents living in central Managua, living with a family and having a close similarity in socioeconomic conditions. The body mass index (BMI), blood iron content and blood lipid concentration in both the child workers and the referents were comparable, indicating similar nutritional status (own data). Their work history was corroborated by local institution records, and is not likely to be misclassified.

We observed a gradient on lead level according not only to working status, but also to vicinity to the dump. One third of referent children living nearby in Acahualinca had B-Pb levels exceeding 50 µg/l, whereas only few children in the reference group from central Managua exceeded this level. A previous study, investigating children from another part of Managua (referents for a study of environmental exposure after the closure of a battery plant) (42), also reported levels below 50 µg/l. The neighbourhood characteristics of Acahualinca - a very poor community, lacking infrastructure and roads (28)- implies that
vehicle traffic intensity is very low. Also, Importation of leaded gasoline in Nicaragua has been restricted since 1995. (43). Thus, it seems likely that the waste disposal site, also by environmental exposure, influences the levels of B-Pb in the Acahualinca children.

The gradient on lead soil content between the waste disposal site area and Acahualinca area supports the presence of the waste disposal site as a source of lead contamination. However, handling of car batteries may also be of concern. A small proportion of the children referred to own or family handling of car batteries in the interview, but we observed no impact on their B-Pb-levels, however this may merely reflect that our question was not sensitive enough. A study in 1996 on lead level in children from Managua (44) reported that 78 (80%) children living nearby an artesanal battery plant and 9 (30%) children living in a referent neighborhood had B-Pb levels exceeding 100 µg/l. Two years after closure of the battery plant, a new monitoring in the same neighborhoods showed that among 70 children only 10 (14 %) had higher levels than 100 µg/l. Regulation of artesanal car battery workshops has been enforced during the last 5 years. However, we identified a few places in Acahualinca at which such handling had taken place or still were said to occur. These places had elevated soil Pb-levels. The ministry of health of Nicaragua (MINSA) identified 37 artesanal car battery workshops located in very populated urban neighborhoods in Managua, in 2002 (45).

There is yet little data on lead exposure in the general population in Managua. Clearly, in our study B-Pb levels in children living far away from the dump were lower than the levels observed in children from urban areas in México (46, 47), Argentina, and Brazil (47). Still, it was almost two-fold the average level shown for US children (10-13 µg/l; (48, 49)).

Although children working at the waste disposal site had higher B-Hg and B-Cd than the referents, the levels of B-Hg and B-Cd observed in all children were much lower than those levels at which health effects have been observed (20-23, 50-54). The B-Hg levels were lower than the levels reported in children and young women from South American countries such as Brazil (55-59) and Ecuador (60, 61), with similar range of age and fish consumption, but living in well documented polluted areas. However, it can be noted that referent children living far from the waste disposal site had 2-3 fold the average B-Hg
concentration of children from United States (48). Also children from a rural community in central Nicaragua not eating fish had similar levels, ranging from 0.4-1.2 μg/l (own data).

As expected, we observed a relationship between fish consumption and B-Hg level among children and in young female high fish consumers, the latter having 5-fold levels compared to young urban women not eating fish. Still, the levels observed were considerably lower than those at which subtle effects on fetal neurodevelopment has been reported. Thus, there seems to be no reason for restrictive fish consumption advisories. Limiting the consumption of fish may do more harm than good by reducing the consumption of foods with health benefits (62).

Selenium is an essential trace element and has been shown to be a natural component in the enzyme glutathione peroxidase and other proteins. Selenium may also prevent or alleviate toxic effects of arsenic, cadmium, mercury, platinum, and silver (24, 25). There is a well known geographical variation in soil selenium content (25). High levels of selenium in soil have been reported from Venezuela (26) but, overall, there is little data on selenium available from Central and Latin America. The B-Se level reported in our study may be considered as proper level for human health (25) and suggests, besides indicating high fish consumption as a dietary source, that Nicaraguan soils are naturally rich in Se.

In conclusion, our study results imply that lead exposure should be of concern. B-Pb levels observed in waste disposal site child workers and in children living in Acahualinca are directly relevant for health risk assessment, not only for these children but also for the next generation. There is a current concern regarding potential neurodevelopmental effects at fetal exposure levels as low as 50-60 μg/l and many of the examined girls will be mothers in the near future. As many as 21% of adolescent females in Managua are mothers or pregnant (64). For the general population of children in Managua, presently available human data are still scarce and not representative enough. Considerations rising from our study indicate a need of understanding about the exposure cycle to lead in the environment and at the waste disposal site and in Managua. The exposure situation needs to be better characterized, and the sources of exposure identified. Also, attention on the producer
responsibility, i.e. the responsibility for production and handling process of lead within the life-cycle perspective, should be part of the consideration.

ACKNOWLEDGEMENTS

We gratefully acknowledge the cooperation of the children participating in the study and their parents, the staffs from “Dos Generaciones” and “Chateles Project”, the authorities from the local primary school and the local health centers during the field work. We also acknowledge Adolfo Salinas and Salvador Hernández for their dedication to the field work.

Tommy Olsson performed the soil analyses, and Anna Akanatis and Giovanni Ferrari performed the blood metal analyses. Valuable comments on the manuscript were given by Maria Albin and Lars Hagmar. The study was funded by the Swedish International Agency for Research Cooperation with Developing countries, SAREC, within the frame of a multidisciplinary co-operation program between Lund University and the National Autonomous University of Nicaragua (UNAN-Managua).

REFERENCES


3. ILO-IPEC2004. Estudio de línea de base. Trabajo infantil en el botadero de basura de Tegucigalpa, Honduras [Base line study. Child labour at Tegucigalpa waste disposal site, Honduras] [In Spanish]. International Labour Office (ILO),
International Programme on the Elimination of Child Labour (IPEC), San José, Costa Rica, 54 pp.


27. IDESO/UCA 2001. *Estudio de línea basal: Programa eliminación progresiva del trabajo infantil en el basurero de Managua La Chureca* [Base line study: Program on progressive elimination of child labour at Managua city dump La Chureca] [In Spanish]. Instituto de Encuestas y Sondeos de Opinión-Universidad Centro Americana (IDESO/UCA), Managua.

28. Borge & Asociados 2000. *Estudio diagnóstico sobre la generación de ingresos alternativos o complementarios, oportunidades y potencialidades de y para los niños de Acualalina [Diagnostic study on generation of alternative or complementary incomes, opportunities, and potentialities of and for children from Acualalinca] [In Spanish]. Centro Nicaraguense de Promoción de la Juventud y La Infancia "Dos Generaciones", Managua, 72 pp.


31. Fäldt, E., Cuadra, S.N., Athanasiadou, M., Bergman, Å. and Jakobsson, K. 2005. Polybrominated dihenyl ethers (PBDEs) in serum from children working in a waste disposal site, and in women with high consumption of fish in Nicaragua. *Organohalogen compounds* 0, 0-0.


45. Lozano, M. 2002. Inventario de talleres artesanales de plomo en Managua [Inventory of lead artesanal workshops in Managua] [In Spanish]. Boletín Epidemiológico No. 19, 23.


Table 1: Sociodemographic characteristic for children working at the waste disposal site and referents

<table>
<thead>
<tr>
<th>Groups</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Attending school (n)</th>
<th>Fish meals/month</th>
<th>Domicile</th>
<th>Location</th>
<th>Age of Onset</th>
<th>Years worked</th>
<th>Hours/day</th>
<th>Days/week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>24</td>
<td>18</td>
<td>8.5 (6-15)</td>
<td>37</td>
<td>1</td>
<td>7</td>
<td>At the dump</td>
<td>7 (2-12)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Group 2</td>
<td>35</td>
<td>26</td>
<td>12 (6-15)</td>
<td>51</td>
<td>1</td>
<td>10</td>
<td>Acahualinka</td>
<td>8 (1-13)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Group 3</td>
<td>27</td>
<td>32</td>
<td>12 (6-15)</td>
<td>57</td>
<td>2</td>
<td>8</td>
<td>Acahualinka</td>
<td>3 (1-12)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Group 4</td>
<td>18</td>
<td>25</td>
<td>11 (6-15)</td>
<td>41</td>
<td>0</td>
<td>8.5</td>
<td>Acahualinka</td>
<td>- (1-14)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Group 5</td>
<td>19</td>
<td>15</td>
<td>12 (6-14)</td>
<td>34</td>
<td>0</td>
<td>7</td>
<td>Remote area</td>
<td>- (0-14)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1 Data are given as medians and ranges, unless stated otherwise.

n= number of subjects

M= male F= female
Table 2: Blood concentration (μg/l) of lead and others heavy metals in children working at the waste disposal site and referents and in high fish consumers from Lake Xolotlán and referents.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number of subjects</th>
<th>Fish meals/month</th>
<th>Waste disposal site</th>
<th>Pb µg/L</th>
<th>Hg µg/L</th>
<th>Cd µg/L</th>
<th>Se µg/L</th>
<th>Fe mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M P10 P90</td>
<td>M P10 P90</td>
<td>M P10 P90</td>
<td>M P10 P90</td>
<td>M P10 P90</td>
</tr>
<tr>
<td>Children</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>42</td>
<td>(0-12) Work, live</td>
<td>77 43 163</td>
<td>1.2 0.53 4.5</td>
<td>0.21 0.13 0.31</td>
<td>180 160 210</td>
<td>470 380 560</td>
<td></td>
</tr>
<tr>
<td>Group 2</td>
<td>61</td>
<td>(0-12) Work</td>
<td>66 37 147</td>
<td>1.3 0.51 4.3</td>
<td>0.20 0.14 0.35</td>
<td>200 170 240</td>
<td>470 400 640</td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td>59</td>
<td>(1-8) No</td>
<td>39 23 69</td>
<td>0.99 0.47 3.3</td>
<td>0.16 0.10 0.33</td>
<td>190 160 230</td>
<td>460 400 510</td>
<td></td>
</tr>
<tr>
<td>Group 4</td>
<td>43</td>
<td>(0-4) No</td>
<td>42 22 78</td>
<td>0.60 0.20 2.0</td>
<td>0.17 0.10 0.30</td>
<td>190 160 220</td>
<td>450 410 490</td>
<td></td>
</tr>
<tr>
<td>Group 5</td>
<td>34</td>
<td>(0-4) No</td>
<td>28 15 49</td>
<td>0.62 0.27 2.5</td>
<td>0.18 0.10 0.27</td>
<td>190 160 210</td>
<td>440 390 490</td>
<td></td>
</tr>
<tr>
<td>Group 1+2 vs 3+4+5</td>
<td></td>
<td></td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>-</td>
<td>p=0.003</td>
<td></td>
</tr>
<tr>
<td>Fish-consumers vs non-consumers2</td>
<td></td>
<td></td>
<td>p=0.004</td>
<td>p=0.026</td>
<td>-</td>
<td>p=0.016</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Young women</th>
<th>M (range)</th>
<th>M (range)</th>
<th>M (range)</th>
<th>M (range)</th>
<th>M (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mateares</td>
<td>5 (4-16)</td>
<td>42 (18-120)</td>
<td>2.3 (0.75-3.8)</td>
<td>0.38 (0.09-0.64)</td>
<td>220 (190-270)</td>
</tr>
<tr>
<td>San Francisco</td>
<td>6 (4-12)</td>
<td>22 (18-44)</td>
<td>2.6 (0.98-5.5)</td>
<td>0.12 (0.11-0.20)</td>
<td>240 (170-300)</td>
</tr>
<tr>
<td>Referents</td>
<td>4 (0-12)</td>
<td>11 (9.7-15)</td>
<td>0.50 (0.22-1.8)</td>
<td>0.15 (0.09-0.22)</td>
<td>160 (140-210)</td>
</tr>
</tbody>
</table>

nd= no detected
M= median
P10= percentile 10
P90= percentile 90
1 For description of groups, see Table 1
2 Mann-Whitney U-test, p-values above 0.2 are not given
Table 3: Blood lead levels (B-Pb) in children working at the waste disposal site, and in referents.

<table>
<thead>
<tr>
<th>B-Pb</th>
<th>Child workers at the waste disposal site (group 1+2)</th>
<th>Non-working children living nearby the waste disposal site (group 3+4)</th>
<th>Non-working children living far from the waste disposal site (group 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median (range)</td>
<td>73 (17-423)</td>
<td>40 (11-138)</td>
<td>28 (11-68)</td>
</tr>
<tr>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>&lt; 50 µg/l</td>
<td>23</td>
<td>65</td>
<td>64</td>
</tr>
<tr>
<td>50-99 µg/l</td>
<td>51</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>≥100 µg/l</td>
<td>29</td>
<td>2</td>
<td>2.</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
<td>102</td>
<td>100</td>
</tr>
<tr>
<td>Area</td>
<td>Place</td>
<td>Pb</td>
<td>Cr</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>--------------------------------------</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>Waste disposal site “La Chureca”</td>
<td>Home (n=11)</td>
<td>93</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Playground at school (n=1)</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Common area (n=1)</td>
<td>84</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Dealers area at “La Chureca” (n=1)</td>
<td>59</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Road into “La Chureca” (n=2)</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Home with current or past car</td>
<td>36</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Playground at school (n=1)</td>
<td>276</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Common areas (public parks) (n=3)</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Centro Dos Generaciones (n=1)</td>
<td>15</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 4: Metal content in soil (ppm, µg/g) from the waste disposal site and from the nearby area, Acahualinca

<table>
<thead>
<tr>
<th>Area</th>
<th>Place</th>
<th>Pb</th>
<th>Cr</th>
<th>Cu</th>
<th>Ni</th>
<th>V</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearby neighborhood, “Acahualinca”</td>
<td>Home (n=9)</td>
<td>36</td>
<td>12</td>
<td>186</td>
<td>29</td>
<td>168</td>
<td>319</td>
<td>61586</td>
</tr>
<tr>
<td></td>
<td>Home with current or past car</td>
<td>276</td>
<td>29</td>
<td>242</td>
<td>39</td>
<td>193</td>
<td>786</td>
<td>62229</td>
</tr>
<tr>
<td></td>
<td>Playground at school (n=1)</td>
<td>25</td>
<td>14</td>
<td>212</td>
<td>28</td>
<td>164</td>
<td>311</td>
<td>64854</td>
</tr>
<tr>
<td></td>
<td>Common areas (public parks) (n=3)</td>
<td>15</td>
<td>9</td>
<td>187</td>
<td>30</td>
<td>179</td>
<td>145</td>
<td>65183</td>
</tr>
<tr>
<td></td>
<td>Centro Dos Generaciones (n=1)</td>
<td>15</td>
<td>11</td>
<td>183</td>
<td>28</td>
<td>174</td>
<td>265</td>
<td>58670</td>
</tr>
</tbody>
</table>

Home at La Chureca vs home at Acahualinca:
p=0.13 p=0.02 - p=0.001 - -
LEGENDS AND FIGURES

Figure 1. Map of Managua, Nicaragua. Locations of the fishing villages Mateare, San Francisco Libre, urban Managua and waste disposal site La Chureca and neighbourhood area Acahualinca are given (elaborated by Emilie Stroh).

Figure 2. Blood lead concentrations (Pb-B; \( \mu g/l \)) by sex and study group. Medians, ranges and outliers are given. Group 1: Children working and living at the waste disposal site. Group 2: Children working at the waste disposal site, living nearby. Group 3: Referent children, living nearby the waste disposal site, eating fish. Group 4: Referent children, living nearby the waste disposal site, not eating fish. Group 5: referent children living in urban Managua far from the waste disposal site, not eating fish.
Figure 3. Blood mercury concentration (B-Hg; μg/l) by level of fish consumption in referent children. Medians, ranges, and outliers are given.
Persistent organochlorine pollutants in children working at a waste disposal site, and in young females with high fish consumption in Managua, Nicaragua

Steven N. Cuadra 1,3, Linda Linderholm2, Maria Athanasiadou2, Kristina Jakobsson1,3

1The Faculty of Medical Sciences, Universidad Nacional Autónoma de Nicaragua-Managua (UNAN-Managua), Apartado Postal # 663 Managua, Nicaragua.
2Department of Environmental Chemistry, Stockholm University, SE-106 91 Stockholm, Sweden.
3Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden.

Address correspondence to: Steven N. Cuadra, Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden.
Telephone: +46-46 177288. Fax: +46-46 17 36 69. E-mail: steven.cuadra@med.lu.se

ABSTRACT
The aim of this study was to assess persistent organochlorine pollutant (POP) levels in serum collected from children (11-15 years) working and sometimes also living at the municipal waste disposal site in Managua, located at the shore of lake Managua, and in non-working children living both nearby and also far away from the waste disposal site. The influence of fish consumption was further evaluated by assessing POPs levels in serum from young women (15-24 years) with markedly different patterns of fish consumption from lake Managua. 4,4’-DDT, 4,4’-DDE, γ-HCH, PCBs, PCP and OH-PCBs were quantified in all samples. In general the levels observed were higher than those reported in children from developed countries such as Germany and United States. Toxaphene, aldrin, dieldrin, and β-HCH could not be identified in any sample. The children working at the waste disposal site had higher levels of POPs, compared to the non-working reference groups. In children not working there were also gradients for several POPs, according to vicinity to the waste disposal site. Moreover, in children as well as in young women there were gradients according to fish consumption. The most abundant component was 4,4’-DDE, but at levels still lower than those reported in children from malarious area with history of recent or current application of 4,4’-DDT for vector control.

Keywords: Persistent organochlorine pollutants, Children, p,p’-DDE, polychlorinated biphenyls, PCBs, pentachlorophenol, PCP, Nicaragua
INTRODUCTION

Persistent organochlorine pollutants (POPs) are chemicals accumulating in lipids in living organisms and increasing in quantity up the food webs. In non-occupationally exposed human populations exposure to POPs comes mostly from dietary sources but occasionally also through inhalation of contaminated soil and dust. Twelve POPs, including 9 pesticides, have been identified by the United Nations Environment Programme as powerful threats to the health of humans and wildlife and have been targeted for elimination (1).

Some toxic chemicals such as polychlorinated biphenyls (PCBs), which have been banned or restricted in the developed countries, may still be used in developing countries (2). It seems that the levels of chlorinated pesticides that were widely used in the past are now declining in many parts of the world because of regulatory measures such as banning and use restriction (2-4). Recent reports show that human populations in some countries in Africa, Asia and Latin America have ongoing exposure to 2,2-bis(4-chlorophenyl)-1,1,1-trichloro-ethane (4,4’-DDT) and 2,2-bis(4-chlorophenyl)-1,1-dichloro-ethene (4,4’-DDE), and the levels of these compounds are higher than in Europe and the United States (3, 4). There is however a lack of information about the level of POPs in the Latin American region (5-7). Especially, concentration data of POPs in children are scarce.

Organochlorine pesticides have been reported to be present in agricultural areas (i.e. cotton, coffee and rice fields) in all Central American countries. 4,4’-DDT and its metabolites, aldrin, lindane, and endosulphane have been the most widely reported pesticides in different levels of the ecosystems (7). However, most data are from the 1980’s. In the traditional cotton growing areas of Nicaragua traces of POPs, mainly organochlorine pesticide, have been detected in cow’s milk (8), sediments (9), water (10), soil (11), and in human adipose tissue (12, 13), cord and venous blood (13), and in breast milk (13, 14).

Managua, the capital of Nicaragua, is situated at the shore of lake Managua, also known as lake Xolotlán. The lake, which is the second largest lake in Nicaragua, is used as the
recipient of domestic and industrial wastewater from the city and receives the superficial run-off from its drainage basin, which is intensively cultivated (15). Fish from lake Managua is an important part of the diet of the population living in poor communities located at the lakeshore. Toxaphene was produced between 1965 and 1991 at a plant located at the lakeshore and all residual wastes were deposited into the lake (16). In 1991 toxaphene, 4,4'-DDT and its metabolites were detected in specimens from the two most highly consumed fish species and also in sediment samples collected from lake Managua (17). 4,4'-DDT was used in vector control programs in Nicaragua until 1991 (18), but illegal use still occurs (19).

The municipal domestic and industrial waste disposal site “La Chureca” in Managua is located on the south shore of lake Managua, covering an area of 7 km² (Fig.1). Approximately 1000 persons, of which more than 50% are children under age 18, work at the waste disposal site (Photo 1) and some of them also live there (Photo 2). Recollection, classification, selling, storing, and cleaning of recyclable waste are the most common activities. Children usually are involved in more than one activity, most frequently handling glass, metals, and plastic. Often, the material is stored at home. Recollection of food from the waste disposal site for self-consumption is also reported (20, 21). A thick cloud of smoke covers the area since the waste is burned to retrieve iron and other materials. The waste is not compressed, the sun is intense, and a constant breeze from the lake sweeps the area. Thus, substantial amounts of airborne dust are generated (Photo 3). Working at the waste disposal site is considered as one of the worst forms of child labour in Nicaragua (22, 23).

The aim of the present study was to assess POPs levels in serum collected from children working and sometimes also living at the waste disposal site i.e. a study group with potential work exposure. The influence of dietary exposure was further evaluated by assessing POPs levels in serum from young women that were high consumers of fish from the lake Managua. Also, appropriate reference populations were investigated. The study is part of a larger research project that includes heavy metal exposure, exposure to air contaminants, respiratory health, and injuries in children working at the waste disposal site. The Ethic’s committees of Lund University and The National Autonomous University of Nicaragua-Managua (UNAN Managua) approved the study protocol.
MATERIALS AND METHODS

Study populations and sampling
The children study and reference groups were established with the help of local non-governmental organizations working in child labour eradication programs. Children between 11 and 15 years old were invited to participate in the study; 64 children working at the waste disposal site, living there or in a nearby area (Acahualinca), 80 children not working at the waste disposal site and living in the Acahualinca area, and 18 children not working at the waste disposal site and living between 10-20 km away from the waste disposal site in the south and central areas of Managua (Fig.1). All children shared the same socioeconomic conditions, and the distribution of age and sex was similar between groups. The participation rate was 90% for waste disposal site workers, 70 % for referents living nearby and 100% for the remote reference group. The blood sampling took place in May and June 2002.

Detailed information on waste disposal site work and dietary habits, especially fish consumption, was obtained by a structured interview. Blood was drawn from the cubital vein into evacuated plain tubes (Vacutainer, Rutherford NJ), and centrifuged. The serum was transferred to acetone-washed glass bottles, frozen and kept at -20°C until chemical analysis in Sweden.

The subjects were stratified by waste disposal site work experience, area of living, and fish consumption, and five distinct serum pools were prepared using criteria described below.

Pool #1: children living at the waste disposal site, currently working, and having worked there for 4 years or more, eating fish from the lake (N=11).
Pool #2: children living in a near-by area, Acahualinca, currently working at the waste disposal site, and having worked there for 4 years or more, eating fish from the lake (N=23).
Pool #3: children living in Acahualinca, having never worked at the waste disposal site, eating fish from lake Managua (N=16).
Pool #4: children living in Acahualinca, having never worked at the waste disposal site, not eating fish (N=10).
Pool #5: children living in a remote urban area and not eating fish (N=11).
For description of sociodemographic characteristics and fish consumption, see Table 1.

Young females with markedly different patterns of fish consumption were also included in our study in order to investigate a wider range of POP exposure through fish consumption. Thus venous blood samples were obtained from young women living in fishermen’s families from two traditional fishing villages. These women were identified by help from the local health centers. Five women aged 15-17 from San Francisco Libre situated on the rural northeast side of lake Managua and four women aged 15-22 from Mateare situated on the southwest shore of the lake, 25 km from the city of Managua participated (Fig.1). Their fish consumption was median 8 (range 4-16) fish meals/month. As referents, four women from urban Managua, aged 18-24 and living in similar socioeconomic conditions, who never ate fish, were used (Table 2). The blood sampling was carried out in July 2002.

Chemical analysis

The extraction and clean up of samples was performed as described elsewhere (24). Neutral and phenol-type compounds were separated by solvent-solvent partition. The lipid removal step chosen was sulfuric acid treatment for both neutral and methylated phenol-type substances, followed by an additional clean up step on silica gel impregnated with conc. sulfuric acid columns (2:1 w/w, 1 g). A slight modification of the method was that the fraction containing the phenol-type compounds was eluted with 10 ml of dichloromethane (DCM) through a sulfuric acid/silica gel column. All solvents used were of the highest available commercial grade. Determinations of lipid weight (l.w.) were done gravimetrically after complete evaporation of the solvent.

Identification and quantification were performed using a Varian 3400 gas chromatograph (GC) with an electron capture detector (ECD) as described by Hovander et al. (24). The column used was a DB5 column (30 m x 0.25 mm i.d., 0.25 μm film thickness). Authentic reference standards, mostly synthesized in house, were used as standards. The surrogate standards were: CB199, used for analysis of neutral compounds and 4-OH-CB193 and 2,4,5-trichlorophenol for halogenated phenolic compounds (HPCs). Injection standards (CB199 for phenol fraction, CB189 for the neutral fraction) were used for quantification and calculation of the recovery to evaluate
the reproducibility of the method. The recoveries of the surrogate standards were 96% (S.D. 5.6%) for CB199, 87% (S.D. 6.3%) for 4-OH-CB193, and 65% (S.D. 20%) for 2,4,5-trichlorophenol.

RESULTS

Pesticides and polychlorinated biphenyls (PCBs) were detected in all samples. The most abundant compound in the neutral fractions was 4,4’-DDE, but 4,4’-DDT and γ – hexachlorocyclohexane (γ-HCH; lindane) were also present. In contrast, toxaphene, aldrin, dieldrin, and β-hexachlorocyclohexane (β-HCH) could not be identified in any sample. A hexachlorobenzene (HCB) peak was observed in some of the subjects, but not quantified. Pentachlorophenol (PCP) was the major peak in the phenolic fractions, except from the children working at the waste disposal site, who had an unknown HPC peak as the highest. Several polychlorobiphenylols (OH-PCBs) were found, of which only the most abundant congener, 4-hydroxy-2,2’,3,4’,5,5’,6-heptachlorobiphenyl (4-OH-CB187), was quantified.

The concentrations of POPs and HPCs quantified in individual and pooled samples are given in Table 2 and 3. The children working at the waste disposal site had higher levels of 4,4’-DDT, 4,4’-DDE, γ-HCH, several PCB-congeners, PCP and 4-OH-CB187, compared to the non-working reference groups. An increased level of PCP was also observed among the children who lived and worked at the waste disposal site. In children not working at the waste disposal site there were also gradients for several POPs, according to vicinity to the waste disposal site, and to fish consumption.

The young women from the fishing villages with high consumption of fish from lake Managua had numerically higher concentrations of 4,4’-DDE, γ-HCH, ΣPCB and several PCB-congeners and 4-OH-CB187, compared to urban women not eating fish (Table 2 and 3).
DISCUSSION

Our data suggest an occupational and environmental exposure to POPs in children at the waste disposal site. Consumption of fish from lake Managua also may influence the levels of some POPs such as PCBs. However, the levels observed were clearly lower than those at which adverse health effects have been reported (25-27).

In young women with varying fish consumption individual samples were analyzed. It has to be kept in mind that the number of subjects is very small, thus statistical testing has it’s inherent limitations, and observed numerical differences do not always reach statistical significance. In the children a study design with pooled samples was used. The reason for this was two-fold - for economical reasons we had no possibility to analyse individual samples for all subjects, and for ethical reasons we wanted to keep the amount of blood sampled as low as possible in this population of malnourished children and teenagers. The exposure levels obtained in our pooled samples are equivalent to mean group levels, but we have no information on the individual variation and thus no possibility for statistical testing, which has to be considered when comparisons between groups are made. To overcome this limitation, we instead carefully selected the subjects to be included in the pools, in order to have them clearly different with regard to the primary factors that we wanted to investigate (waste disposal site work exposure, area of living), but as homogenous as possible with regard to factors that we - based on previous knowledge from the literature - assumed would influence POP levels (fish consumption, age). The child workers were compared with non-workers living both nearby but also far away from the waste disposal site. Their labour history was corroborated with local institution records. Non-workers assembled in pools 3-5 represent Managua children in low socioeconomic strata. The question on fish consumption was easily understood by the subjects, and was not in focus during the interview. Thus, the risk for differential misclassification of exposure is low.

Pesticides such as toxaphene, aldrin, dieldrin, and β-hexachlorocyclohexane that have been reported previously in humans, biota and other environmental samples from Nicaragua (8-17, 28) were not identified in the present study. The production of toxaphene in a plant at the lakeshore ceased in year 1991. At that time toxaphene was found in fish tissues samples from lake Managua (17), and in breast milk samples from
16 mothers living in Managua (28). However, no data are available on current levels of toxaphene in water, sediment and fish tissues from the lake. It is known that the various toxaphene components are differently transformed in the environment; some are highly persistent, but others are rapidly degraded (29-33). Therefore it is difficult to draw any conclusion from the present data regarding the actual levels of toxaphene in the environment. The absence of the other pesticides mentioned may reflect the banning of these compounds during the 1980’s (7).

Children working and living at the waste disposal site and the young women from the fishing villages had the highest levels of 4,4’-DDE (Table 2), the most persistent metabolite of 4,4’-DDT which can remain in the environment for many years (34). The high 4,4’-DDE/4,4’-DDT ratio suggests that the exposure to DDT in our study group is from the past (3, 4, 34). The group differences are reasonable, as 4,4’-DDT was likely to be more extensively used for vector control at the waste disposal area and in the villages at the lakeshore, compared to the central urban areas (35). Also, the differences observed between the young women from the two fishing communities (Table 2) can be explained by the fact that the Mateare area was in the past extensively cultivated, in contrast to the San Francisco Libre area.

A comparison with contemporary studies reveals that the levels of 4,4’-DDE found in our study are lower than the levels reported in children from a malarious area in México with a history of recent or current application of 4,4’-DDT for vector control (Table 4), but much higher than those reported in children from developed countries such as Germany (36-39) and United States (40) (Fig.2). Also, the levels of 4,4’-DDE observed in our study were higher than the levels in children from Brazil, Honduras and México living in non-malarious areas (Table 4). Similarly, during the first half of the 1990’s, the 4,4’-DDT and 4,4’-DDE levels in Nicaraguan mother’s milk were lower than in other Latin American and African countries, with recent history of DDT use, although higher than in countries in which the DDT ban was enforced (14). Even though the levels of 4,4’-DDT and p,p’-DDE observed in our study group were not alarmingly high, ongoing exposure to 4,4’-DDT in the Nicaraguan population should still be of concern. In Nicaragua DDT was banned in 1980 for agricultural purposes and the last legal application for vector control was reported in Nicaragua in 1991 (35), but there are recent reports showing a constant use of DDT by the people (19) and illegal trade of
DDT coming from contraband activities (18, 35). Thus, the magnitude of domestic and local DDT use in Nicaragua is still an open issue, and monitoring of exposure to already banned pesticides is still needed.

Food generally accounts for the majority of PCB intake (41, 42). In our study, fish consumption also seems to contribute to the levels of PCBs in children and young women, as expected. A numerically difference on PCB levels regarding fish consumption was observed, but not reaching statistical significance in the case of young women (Table 2 and 3). However, it also seems that the waste disposal area was a source of local contamination for PCBs. Notably, the children working at the waste disposal site appear to have higher PCB levels than young women from the fishing villages with much higher fish consumption. The CB153 levels in children working at the waste disposal site and in the young women from fishermen’s families were comparable to those found in fishermen’s wives (43) and in no- or low fish consumers (44) living around the Baltic Sea, in Spanish adults (45) and in pregnant Faroe women not consuming pilot whale blubber (46), in which median CB153-levels in the range 150-200 ng g⁻¹ l.w. were reported. Moderate and high fish consumers from the Baltic Sea area had concentrations up to 500-1000 ng g⁻¹ l.w. or more, and even higher levels have been observed in Faroe and Inuit populations (46, 47). There are evidences that the levels of PCBs and some but not all POPs have been decreasing during the last decades in industrialized countries (48). Also, it has been suggested, mainly from data on mother’s milk, that PCB levels tend to be lower in the general population from slightly or not industrialized regions (2, 41), compared to highly industrialized areas. However, in our study the CB153 levels observed among urban poor children not working at the waste disposal site were higher than the levels reported in children from Germany (37-39) and United States (40, 49) (Fig.2). Previous data on PCBs are scarce for Latin American population (2, 5), and data from children are entirely lacking. The levels of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, and HCB in a pooled sample of breast milk from 40 mothers living in the city of Rio de Janeiro were lower compared to concentrations generally found in more industrialized countries (50).

Levels of hydroxylated metabolites of PCBs have not been reported from Latin America previously. Again, the waste disposal site workers had the highest levels of 4-
OH-187 (Table 2), comparable to levels found in pregnant Faroe women that are low consumers of pilot whale blubber (median 4-OH-CB-187 serum level of 37 ng gr⁻¹ l.w.) (46) and in Canadian Inuit women (geometric mean 4-OH-CB-187 whole blood level of 0.152 ng gr⁻¹ f.w.), but higher than southern Quebec population (mean 4-OH-CB-187 whole blood level of 0.031 ng gr⁻¹ f.w.) (47).

The lindane (γ-HCH) levels in non-working children and referents women (Table 2) were comparable to those reported in children from United States (median γ-HCH serum level < 10.5 ng gr⁻¹ l.w.) (40), Germany (median γ-HCH plasma level < 0.1 ng ml⁻¹ f.w.) (36) and in general population (including adults and children) from Rio de Janeiro Brazil (median γ-HCH serum levels ranged 0.07-0.09 ng ml⁻¹ f.w.) (51). Children working at the Managua waste disposal site had higher levels of lindane.

The waste disposal site seems to be a source of specific local contamination for PCP. The children working at the waste disposal site had PCP levels about two-fold higher than the levels recently reported in children from Germany (36, 52), but comparable to those reported during the early 1990’s in German children (52) and Swedish and Latvian men (44). No data on the presence of PCP in the environment in Nicaragua or its industrial use was available to us. On the order hand, a number of other chemicals, including HCB, pentachlorobenzene, and benzene hexachloride isomers, are known to be metabolized to PCP (53).

The levels observed in our study groups are directly relevant for risk assessment with regard to reproductive outcomes, since as many as 21% of adolescent females in Managua in 2001 were mothers or pregnant (54). Clearly, monitoring of POPs exposure in Latin America is of importance to give guidance for actions to control the human exposure. This includes environmental data as well as human data from the general population, and from vulnerable populations like children and adolescents in extreme socioeconomic conditions with multiple hazardous exposures. Especially, time trend studies are urgently needed. On the other hand, even if consumption of fish from lake Managua is indicated to be a source of POPs exposure, the benefits of fish consumption would outweigh risk (55), and our findings support no restrictions on fish consumption.
ACKNOWLEDGEMENTS

We gratefully acknowledge the cooperation of Dr Danilo Hernandez Romero, Dr Mario Jiménez, Dr Gustavo Sequeira, Adolfo Salinas, the staffs from “Dos Generaciones” and “Chateles Project” and the local Health Centers during the field work, and the support from professor Sören Jensen and professor Åke Bergman. The map was elaborated by Emilie Stroh. The study was funded by the Swedish International Agency for Research Cooperation with Developing countries, SAREC, within the frame of a multidisciplinary co-operation program between Lund University and the National Autonomous University of Nicaragua-Managua (UNAN-Managua).
REFERENCES AND NOTES


(http://www.ops.org.ni/Plaguicidas/ppprincipal.htm)  
(http://www.ops.org.ni/Plaguicidas/Documentos/autodiagnostico_vecores.doc)  
(http://www.ipec.oit.or.cr/ipec/region/paises/nicaragua.shtml)  


59. When concentration is given in whole blood or plasma/serum fresh weight (f.w.) basis, a plasma/serum lipid weight (l.w.) equivalent can be estimated by two steps as follow: 1) from whole blood f.w. basis to plasma or serum f.w. basis: the concentration of the given compounds is divided by two. 2) lipid correction: the plasma or serum concentration is dived by the lipid content. When the lipid content is not reported it can be assumed that 1 g plasma contains 0.0060 g lipids (0.6% lipids). However, the lipid content varies from one population to another, especially in children in whom even lower lipid contents are expected.

60. In order to elaborate the waste disposal site map some materials were obtained as "Courtesy of the University of Texas Libraries, The University of Texas at Austin".
AUTHOR'S BIOGRAPHY

1) Steven N. Cuadra, MD, is a Lecturer at The Faculty of Medical Sciences, National Autonomous University of Nicaragua-Managua (UNAN-Managua). Currently, He is a PhD student in Environmental Medicine at the Department of Occupational and Environmental Medicine, Lund University. He is investigating exposure to persistent organic pollutants (POPs) and heavy metal in vulnerable population in Nicaragua. His addresses: Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden. In Nicaragua: Facultad de Ciencias Médicas, Universidad Nacional Autónoma de Nicaragua-Managua (UNAN-Managua), Apartado Postal # 663 Managua, Nicaragua. E-mail: steven.cuadra@med.lu.se

2) Linda Linderholm is a Research Assistant at the Department of Environmental Chemistry at Stockholm University when this study was performed. She has a M.Sci. in chemistry and she has worked with analysis of organohalogen substances since 2002. Her address: Department of Environmental Chemistry, Stockholm University, SE-106 91 Stockholm, Sweden. E-mail: linda.linderholm@mk.su.se

3) Maria Athanasiadou has a PhD in environmental chemistry from Stockholm University. She has long experience in analysis of biological environmental samples. She is engaged in methodological development, identification and quantification of organohalogen substances. Her address: Department of Environmental Chemistry, Stockholm University, SE-106 91 Stockholm, Sweden. E-mail: maria.athanasiadou@mk.su.se

4) Kristina Jakobsson, MD, PhD, is associate professor and consultant at the Faculty of Medicine, Lund University. She has studied occupational cancer and respiratory diseases and, more recently, occupational and environmental exposure to brominated flame retardants. Her address is: Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden. E-mail: Kristina.jakobsson@med.lu.se
Table 1 Sociodemographic characteristic for children working at a waste disposal site in Managua and referents

<table>
<thead>
<tr>
<th>Groups</th>
<th>Sex (N)</th>
<th>Age (^1) (years)</th>
<th>Attending primary school (N)</th>
<th>Fish meals/month(^1)</th>
<th>Domicile</th>
<th>Work at waste disposal site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td></td>
<td></td>
<td>Duration of dwelling(^1)</td>
<td>Location</td>
</tr>
<tr>
<td>Pool 1</td>
<td>6</td>
<td>5</td>
<td>14 ((13 - 15))</td>
<td>8</td>
<td>2</td>
<td>(0 - 8)</td>
</tr>
<tr>
<td>Pool 2</td>
<td>16</td>
<td>7</td>
<td>14 ((12 - 15))</td>
<td>17</td>
<td>2</td>
<td>(0 - 8)</td>
</tr>
<tr>
<td>Pool 3</td>
<td>6</td>
<td>10</td>
<td>14 ((11 - 15))</td>
<td>16</td>
<td>2</td>
<td>(2 - 8)</td>
</tr>
<tr>
<td>Pool 4</td>
<td>5</td>
<td>5</td>
<td>14 ((13 - 15))</td>
<td>10</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Pool 5</td>
<td>5</td>
<td>6</td>
<td>13 ((12 - 14))</td>
<td>11</td>
<td>0</td>
<td>12</td>
</tr>
</tbody>
</table>

\(^1\) Median (range)
N= number of subjects
M= male F= female
Table 2  Serum concentration ng g⁻¹ lipid weight (l.w.), ppb and ng g⁻¹ fresh weight, (f.w.), ppb of some POPs in children working at the waste disposal site and referents (pooled samples) and in young female high fish consumers from Lake Managua and referents.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N Fish meals/month¹</th>
<th>Waste disposal site</th>
<th>Lipid weight content (%)</th>
<th>Neutral Fraction</th>
<th>Phenolic Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDE l.w.¹</td>
<td>f.w.¹</td>
</tr>
<tr>
<td>Children</td>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDT l.w.¹</td>
<td>f.w.¹</td>
</tr>
<tr>
<td>Pool 1</td>
<td>11 2 (0-8)</td>
<td>Work, live</td>
<td>0.36</td>
<td>1600</td>
<td>5.7</td>
</tr>
<tr>
<td>Pool 2</td>
<td>23 2 (0-8)</td>
<td>Work</td>
<td>0.37</td>
<td>1200</td>
<td>4.4</td>
</tr>
<tr>
<td>Pool 3</td>
<td>16 2 (2-8)</td>
<td>No</td>
<td>0.38</td>
<td>990</td>
<td>3.8</td>
</tr>
<tr>
<td>Pool 4</td>
<td>10 0</td>
<td>No</td>
<td>0.38</td>
<td>1000</td>
<td>3.8</td>
</tr>
<tr>
<td>Pool 5</td>
<td>11 0</td>
<td>No</td>
<td>0.38</td>
<td>990</td>
<td>3.7</td>
</tr>
<tr>
<td>Young women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mateare</td>
<td>4 8 (4-16)</td>
<td>-</td>
<td>0.46</td>
<td>2800</td>
<td>12.00</td>
</tr>
<tr>
<td>San Francisco</td>
<td>5 4 (4-8)</td>
<td>-</td>
<td>0.58</td>
<td>1450</td>
<td>8.90</td>
</tr>
<tr>
<td>Referents</td>
<td>4 0</td>
<td>-</td>
<td>0.38</td>
<td>790</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>LOQ4</td>
<td>&lt;5</td>
<td>&lt;0.02</td>
<td>&lt;8</td>
<td>&lt;0.03</td>
<td>&lt;12</td>
</tr>
<tr>
<td>p-values5</td>
<td>p=0.2</td>
<td>p=0.25</td>
<td>p=0.01</td>
<td>p=0.05</td>
<td>p=0.25</td>
</tr>
</tbody>
</table>

¹ number of subjects, nd= no detected
² median (range), ³ sum of CB118, 153, 105, 138, 187, 183, 128, and 180
⁴ samples only
⁵ Mann-Whitney U-Test; San Francisco and Mateare vs referents

N= number of subjects, nd= no detected
4 median (range), 5 sum of CB118, 153, 105, 138, 187, 183, 128, and 180
4 samples only
4 LOQ, limit of quantification
5 Mann-Whitney U-Test; San Francisco and Mateare vs referents
Table 3 Serum concentration ng g⁻¹ lipid weight (l.w.), ppb of some PCB congeners in children working at a waste disposal site in Managua and referents (pooled samples) and in young female high fish consumers from Lake Managua and referents.

<table>
<thead>
<tr>
<th>Groups¹</th>
<th>CB105²</th>
<th>CB118²</th>
<th>CB128²</th>
<th>CB138²</th>
<th>CB153²</th>
<th>CB170²</th>
<th>CB180²</th>
<th>CB183²</th>
<th>CB187²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pool 1</td>
<td>26</td>
<td>62</td>
<td>16</td>
<td>149</td>
<td>148</td>
<td>37</td>
<td>89</td>
<td>17</td>
<td>32</td>
</tr>
<tr>
<td>Pool 2</td>
<td>34</td>
<td>77</td>
<td>15</td>
<td>151</td>
<td>139</td>
<td>38</td>
<td>77</td>
<td>13</td>
<td>29</td>
</tr>
<tr>
<td>Pool 3</td>
<td>21</td>
<td>46</td>
<td>11</td>
<td>90</td>
<td>147</td>
<td>20</td>
<td>47</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Pool 4</td>
<td>25</td>
<td>38</td>
<td>12</td>
<td>64</td>
<td>52</td>
<td>nd</td>
<td>24</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Pool 5</td>
<td>26</td>
<td>29</td>
<td>9</td>
<td>37</td>
<td>29</td>
<td>5</td>
<td>19</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Young women</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mateare</td>
<td>16</td>
<td>40</td>
<td>13</td>
<td>100</td>
<td>101</td>
<td>26</td>
<td>70</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>San Francisco</td>
<td>7</td>
<td>11</td>
<td>5</td>
<td>39</td>
<td>45</td>
<td>nd</td>
<td>36</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>(nd - 123)</td>
<td>(nd - 196)</td>
<td>(nd - 49)</td>
<td>(6 - 181)</td>
<td>(7 - 103)</td>
<td>(nd - 22)</td>
<td>(7 - 42)</td>
<td>(2 - 8)</td>
<td>(3 - 16)</td>
</tr>
<tr>
<td>Referents</td>
<td>7</td>
<td>9</td>
<td>3</td>
<td>16</td>
<td>14</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(4 - 76)</td>
<td>(nd - 113)</td>
<td>(2 - 31)</td>
<td>(nd - 105)</td>
<td>(6 - 61)</td>
<td>(nd - 11)</td>
<td>(nd - 18)</td>
<td>(2 - 5)</td>
<td>(2 - 6)</td>
</tr>
</tbody>
</table>

p-values³ | p>0.25 | p>0.25 | p>0.25 | p>0.2  | p=0.1  | p=0.05 | p=0.1  | p=0.1  | p>0.05 |

nd= no detected

¹ For group description, lipid content and fish consumption see Table 1
² median (range)
³ Mann-Whitney U-Test; San Francisco and Mateare vs referents
Table 4  Concentration (ng ml⁻¹ f.w.) of reported POPs in children from Latin American countries.

<table>
<thead>
<tr>
<th>Area / Country and Year of sampling</th>
<th>Subjects</th>
<th>Biological Media</th>
<th>Compounds</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiapas, Mexico 2002 (56)</td>
<td>9 males</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>13.7²</td>
<td>3.8 – 40.1</td>
</tr>
<tr>
<td></td>
<td>6 females</td>
<td></td>
<td>4,4'-DDE</td>
<td>38.4²</td>
<td>5.7 – 115</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDD</td>
<td>2.1²</td>
<td>nd – 14.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ DDT</td>
<td>54.3³</td>
<td>13.4 – 142</td>
</tr>
<tr>
<td>San Luis Potosi, Mexico 2002 (56)</td>
<td>2 males</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td></td>
<td>4 females</td>
<td></td>
<td>4,4'-DDE</td>
<td>0.7</td>
<td>0.5 – 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDD</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ DDT</td>
<td>0.8</td>
<td>0.6 – 1</td>
</tr>
<tr>
<td>Chiapas, Mexico 1998 (57)</td>
<td>7 males</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>67.8</td>
<td>21.8 – 113</td>
</tr>
<tr>
<td></td>
<td>2 females</td>
<td></td>
<td>4,4'-DDE</td>
<td>86.7</td>
<td>50.3 – 167</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDD</td>
<td>1.9</td>
<td>0.7 – 3.3</td>
</tr>
<tr>
<td>Oaxaca, México 2000 (57)</td>
<td>12 males</td>
<td>Whole blood</td>
<td>4,4'-DDT</td>
<td>20.4</td>
<td>7.5 – 53.3</td>
</tr>
<tr>
<td></td>
<td>16 females</td>
<td></td>
<td>4,4'-DDE</td>
<td>74.5</td>
<td>34.9 – 180</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,4'-DDD</td>
<td>1.9</td>
<td>0.5 – 5.1</td>
</tr>
<tr>
<td>Isita, Choluteca, Honduras 1998 (58)</td>
<td>10 males</td>
<td>Serum</td>
<td>4,4'-DDE</td>
<td>51% &gt; 3.5</td>
<td>1.2 – 96.9</td>
</tr>
<tr>
<td></td>
<td>30 females</td>
<td></td>
<td>Aldrin</td>
<td>23% &gt; 0.2</td>
<td>-</td>
</tr>
<tr>
<td>Cubatão, SP, Brazil (51)</td>
<td>44 males</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>2.7</td>
<td>0 – 27.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>2.3</td>
<td>0 – 34.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.8</td>
<td>0 – 4.4</td>
</tr>
<tr>
<td></td>
<td>18 females</td>
<td></td>
<td>Σ DDT</td>
<td>7.0</td>
<td>0 – 56.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>1.7</td>
<td>0 – 18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.7</td>
<td>0 – 4.7</td>
</tr>
<tr>
<td></td>
<td>29 males</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>1.7</td>
<td>0 – 8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>7.6</td>
<td>0 – 12.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.6</td>
<td>0 – 3.5</td>
</tr>
<tr>
<td></td>
<td>20 females</td>
<td></td>
<td>Σ DDT</td>
<td>1.1</td>
<td>0 – 3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>2</td>
<td>0 – 11.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.6</td>
<td>0 – 2.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.6</td>
<td>0 – 2.8</td>
</tr>
<tr>
<td>Cubatão, SP, Brazil (51)</td>
<td>53 males</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>0.97</td>
<td>0 – 9.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>0.01</td>
<td>0 – 0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.07</td>
<td>0 – 2.6</td>
</tr>
<tr>
<td></td>
<td>28 females</td>
<td></td>
<td>Σ DDT</td>
<td>4</td>
<td>0 – 46.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>0.01</td>
<td>0 – 0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0.2</td>
<td>0 – 5.7</td>
</tr>
<tr>
<td></td>
<td>31 males</td>
<td>Serum</td>
<td>Σ DDT</td>
<td>0.5</td>
<td>0 – 4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>0.03</td>
<td>0 – 0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>23 females</td>
<td></td>
<td>Σ DDT</td>
<td>2</td>
<td>0 – 23.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCB</td>
<td>0.01</td>
<td>0 – 0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Σ HCH</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

f.w. = fresh weight, nd= not detected, Σ DDT = DDT + DDE + DDD, Σ HCH = α-HCH + β-HCH + γ-HCH

¹Here, concentrations are given in whole blood or plasma/serum fresh weight (f.w.) basis. For comparison purpose, a plasma/serum lipid weight (l.w.) equivalent can be estimated by lipid correction assuming a serum lipid content of 0.6% (59).
²Geometric mean
³No year of sampling is given.
⁴0= nd, in this study concentrations below the detection limit were assumed as zero for calculation purpose.
Figure 1: Map of Managua, Nicaragua. Locations of Mateare, San Francisco, urban Managua and waste disposal site area (60) are given. (Elaborated by Emilie Stroh)

Photo 1: Not only teenagers but also younger children are working at the waste disposal site, some of them since early childhood. (Photo by Danilo Hernández)
Photo 2: More than 115 families are living within the waste disposal site “La Chureca”, Managua. (Photo by Danilo Hernández)

Photo 3: Children working at the waste disposal site share similar work shift to adults,
facing hard working conditions. (Photo by Adolfo Salinas)

Figure 2: Serum concentration of 4,4'-DDE and CB153 in Nicaraguan children (pooled samples) and children from developed countries. **Pool 3**: Poor children (11-15 years) living nearby a waste disposal site in Nicaragua with low to moderate fish consumption. **Pool 4**: Poor children (11-15 years) living nearby a waste disposal site in Nicaragua, no fish consumption. **Pool 5**: Poor children (11-15 years) living in urban Managua, far from the waste disposal site, no fish consumption. **USA 2001/2002**: Children and adolescents (12-19 years) from general population. In this group the 50th percentile for CB153 concentration was below the maximum limits of detection (LOD), which was reported to be 10.5 ng g⁻¹ l.w. Thus, LOD and 95th percentile for CB153 and 50th and 95th percentiles for 4,4'-DDE are plotted (40). **Germany 1998**: Children (9-11 years) from general population (37). 4,4'-DDE and CB153 median and 95th percentile concentrations for German Children were given in ng ml⁻¹ f.w., therefore values were transformed into ng g⁻¹ l.w., assuming a serum lipid content of 0.6%.
POLYBROMINATED DIPHENYL ETHERS IN SERUM FROM TEENAGERS WORKING IN A WASTE DISPOSAL SITE, AND IN WOMEN WITH HIGH CONSUMPTION OF FISH IN NICARAGUA

Emma Fäldt¹, Steven N. Cuadra²,³, Maria Athanasiadou ¹, Åke Bergman¹, Kristina Jakobsson²

¹Department of Environmental Chemistry, Stockholm University, SE-106 91 Stockholm Sweden
²Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden
³Faculty of Medicine, Universidad National Autónoma de Nicaragua-Managua, Nicaragua

Address correspondence to: Kristina Jakobsson, Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden. Telephone: +46-46 17 7288. Fax: +46-46 17 36 69. E-mail: steven.cuadra@med.lu.se
**Introduction**

Polybrominated diphenyl ethers (PBDEs) have been extensively used as additive flame retardants since the 1970s. PBDEs levels increasing with time have been found in most environmental compartments, including aquatic and terrestrial ecosystems, and in humans (deWit 2002, Sjödin 2003). Most data originate from Europe, North America and the Arctic. From Asia there are reports from Japan, Korea, and Singapore. Information on human PBDE exposure from other regions in the world, except one report from Mexico (REF), is entirely lacking.

The present study reports PBDE-levels in young Nicaraguans. Previously data on their serum levels of persistent organochlorine pollutants (POPs) has been reported (Cuadra et al 2003). In general the levels observed were higher than those reported from developed countries.

**Material and methods**

*Setting:*

Managua, the capital of Nicaragua, is situated at the shore of Lake Xolotlán. The lake, which is the second largest lake of Nicaragua, has been used as the recipient of domestic and industrial wastewater from the city, and receives the superficial run-off from its drainage basin, which is intensively cultivated. Fish from the lake is an important part of the diet, not only for the population living in rural fishing villages, but also for segments of the Managuan population.

The municipal domestic and industrial waste disposal site in Managua is located directly on the south shore of the lake, covering an area of 7 km². Approximately 1000 persons, of which more than 50% are children under age 18, work at the city dump, collecting recyclable waste for selling. A thick cloud of smoke covers the area as the waste is burned to retrieve iron and other materials. Electronic waste is seldom found at the dump site. The waste is not compressed, the sun is intense, and a constant breeze from the lake sweeps the area. Thus, substantial amounts of airborne dust are generated. In 2005, mean levels of particulate matter (PM2.5) in the city dump area were 710...
μg/m³, compared to 110 μg/m³ in a nearby reference area, Acahualinca (Dr D Hernandez Romero, personal communication).

**Study groups:**
We studied teenagers working in the city dump, and referents, all aged 12-15 and sharing the same underprivileged socio-economic situation. 48% were girls. Five serum pools were assembled in May 2002 (for further details see also Table 1): #1: teenagers living at the city dump, having worked there for 4-10 years (median 6 years). Half of the teenagers had been living at the dump all their life, the other half between 5 to 11 years. #2: teenagers living in a near-by area, Acahualinca, having worked at the city dump for 4-12 years or more (median 6 years), #3 and #4: teenagers living in Acahualinca, not working at the dump #5: teenagers living in a remote urban area.

We also assembled another four pools to further study the influence of fish consumption: #A: women aged 15-17, living in fishermen’s families in San Francisco Libre, a fishing village on the rural north-east side of the lake; #B: women aged 20-29 from another fishing village, Mateare, 25 km from the city of Managua. #C: women from urban Managua aged 18-25; #D: women from urban Managua aged 42-44. All were living in similar under-privileged socio-economic conditions. The serum sampling was performed in July, 2002.

**Chemical analysis:**
The chemicals used, extraction of serum, lipid determination, partitioning with an alkaline solution, procedure and analysis have been described in detail elsewhere (Hovander et al. 2000) except that n-hexane was replaced with cyclohexane. Lipids were removed from the extracts by sulfuric acid. Fractions containing both the neutral and phenol type substances were subjected to cleanup on sulfuric acid silica gel columns (1 g). The mobile phase for phenolic compounds dichloromethane (10 ml). Additional cleanup was made for both fractions on an activated (300°C, 12 h) silica gel column (1 g). The columns were conditioned with cyclohexane (6 ml) before the samples were applied. A first fraction was collected in cyclohexane (3 ml) and a second in dichloromethane (6 ml). The solvent in fraction 2 was reduced under a gentle stream
of N₂ and replaced with n-hexane prior to gas chromatography mass spectrometry (GC-MS) analysis. Reference compounds, synthesised in house, were used as standards. All solvents were of the highest available commercial grade. Identification and quantification were performed using a GC-MS Finnigan TSQ 700 (Thermoquest, Bremen, Germany) operating in electron capture chemical ionization (ECNI) mode, tracing the bromide ions \((m/z \ 79\) and 81). A DB-5HT column (15 m × 0.2 mm i.d. and 0.1 \(\mu\)m film thickness) from Supelco (Bellefonte, USA) was used with temperature program of 80°C (1 min) – 15°C/min – 300°C – 2 °C/min – 320°C (2 min). On-column injections were performed using a septum equipped programmable injector fitted with a high performance insert. The injector temperature was 60°C and increased with 150°C /min up to 300°C for each injection. Helium was used as carrier gas. The transfer line temperature was 290°C and the temperature in the ion-source was 200°C.

**Results**

The concentrations of selected PBDE congeners are given in Table 1. In all pools BDE-47 was the dominating PBDE congener, followed by BDE-99, BDE-100 and BDE-153. The teenagers working and living at the plant had by far the highest PBDE-levels, followed by the city dump workers living in a nearby area.

**Table 1.** Concentrations of some PBDEs (pmol/g lipid weight) in teenagers working at a waste disposal site, and referents (pool 1-5), and in women with varying fish consumption (pool A-D). For comparison, levels in Swedish men and US blood donors are also given (from Sjödin et al 2003, Thuresson et al 2005).

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Fish meals/month</th>
<th>Waste disposal area</th>
<th>BDE-47</th>
<th>BDE-100</th>
<th>BDE-99</th>
<th>BDE-153</th>
<th>BDE-183</th>
<th>BDE-203</th>
<th>BDE-209</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool 1</td>
<td>2 (0-8)</td>
<td>Work, live</td>
<td>639</td>
<td>110</td>
<td>308</td>
<td>46</td>
<td>2.4</td>
<td>0.86</td>
<td>5.4</td>
</tr>
<tr>
<td>Pool 2</td>
<td>2 (0-8)</td>
<td>Work</td>
<td>70</td>
<td>18</td>
<td>19</td>
<td>18</td>
<td>2.4</td>
<td>0.70</td>
<td>3.6</td>
</tr>
<tr>
<td>Pool 3</td>
<td>2 (2-8)</td>
<td>No</td>
<td>29</td>
<td>7.3</td>
<td>11</td>
<td>4.5</td>
<td>1.1</td>
<td>0.40</td>
<td>5.7</td>
</tr>
<tr>
<td>Pool 4</td>
<td>0</td>
<td>No</td>
<td>11</td>
<td>2.0</td>
<td>4.6</td>
<td>2.2</td>
<td>2.6</td>
<td>0.47</td>
<td>7.3</td>
</tr>
<tr>
<td>Pool 5</td>
<td>0</td>
<td>No</td>
<td>14</td>
<td>3.4</td>
<td>6.5</td>
<td>2.6</td>
<td>1.0</td>
<td>0.50</td>
<td>6.0</td>
</tr>
<tr>
<td>Pool A</td>
<td>4 (4-8)</td>
<td>-</td>
<td>20</td>
<td>4.2</td>
<td>11</td>
<td>2.2</td>
<td>1.8</td>
<td>0.63</td>
<td>4.5</td>
</tr>
<tr>
<td>Pool B</td>
<td>8 (8-16)</td>
<td>-</td>
<td>14</td>
<td>3.3</td>
<td>3.7</td>
<td>1.6</td>
<td>0.45</td>
<td>0.39</td>
<td>3.7</td>
</tr>
<tr>
<td>Pool C</td>
<td>0 (0-0)</td>
<td>-</td>
<td>86</td>
<td>15</td>
<td>14</td>
<td>12</td>
<td>0.79</td>
<td>0.61</td>
<td>4.1</td>
</tr>
<tr>
<td>Pool D</td>
<td>0 (0-4)</td>
<td>-</td>
<td>68</td>
<td>11</td>
<td>26</td>
<td>5.4</td>
<td>0.48</td>
<td>0.46</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Swedish men 2000**

3.2 0.97 <0.1 0.89 0.16 <0.2 2.5

**US blood donors 2003**

70 13 23 14 - - -

1 Mean of duplicate analyses
Discussion

The teenagers living and working on the city dump had very high levels of low-medium brominated BDEs, higher than hitherto reported elsewhere. Obviously, the city dump is a source of exposure, and inhalation is the likely main route of exposure. Four of the teenagers in pool 1 had been living at the dump all their life. Thus, PBDE exposure in utero had occurred; taken the presumed long half life of low-medium brominated PBDEs into account (several years; Geyer et al 2004) this may partly contribute to their present levels.

PBDE-levels were higher among non-working teenagers eating fish from the lake, compared to the levels observed in non-consumers living in the same area. Thus, fish from the lake may also be a source of exposure to low-median brominated BDEs. This is in line with previous findings of a correlation of fish consumption and the level of BDE-47 (Sjödin et al 1999).

However, factors linked to urban dwelling, whether dietary or others, were clearly much more important for the levels of low- to medium brominated PBDEs than fish consumption, as seen by the contrasts between pools C and D, vs pools A and B. Such a marked urban-rural gradient has not been reported before. We have not detailed dietary information for these subjects, but it is not likely that their diet, which is based on rice and beans, differs markedly expect for fish consumption.

The levels of low- to medium brominated PBDE observed among young and middle aged urban Nicaraguan women were comparable to contemporary observations in US blood donors (Sjödin et al 2003), whereas urban teenagers not working at the dump had lower levels.

The city dump is not only a source of PBDE exposure, but also of other persistent organohalogens as PCB and pentachlorphenol (Cuadra 2003). Moreover, more than one third of the children and teenagers working at the dump had blood lead levels exceeding the action level recommended by CDC (Cuadra, personal communication). Thus, in addition to the extremely harsh living and working conditions encountered by these
children, the complex chemical exposure situation has to be taken seriously. A female teenager is also a mother in the near future – in 2001 as many as 21% of adolescent females in Managua were mothers or pregnant (INIEC 2002).

The present results clearly call for the urgent necessity to monitor human PBDE exposure not only in the industrialized regions of the world, but also in developing countries and in underprivileged populations.

**Acknowledgements**

We gratefully acknowledge the cooperation of Dr Danilo Hernandez Romero, and the staff from “Dos Generaciones”, “Chateles project”, and health centers in the study areas during the field work. The study was performed within the framework of a multidisciplinary co-operation project between Lund University and the Autonomous University of Nicaragua (UNAN-Managua), funded by the Swedish International Agency for Research Cooperation with Developing countries, SAREC

**References**


Work related injuries in children working at a waste disposal site in Nicaragua, and in referents

Steven N Cuadra 1,2, Anna Axmon 2, Danilo Hernández 1,2, Mario Jiménez 1, Maria Albin 2, Kristina Jakobsson 2

1 Department of Preventive Medicine, Faculty of Medical Sciences, National Autonomous University of Nicaragua-Managua (UNAN-Managua), Postal Code # 663, Managua, Nicaragua.
2 Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden

Address correspondence to: Steven N. Cuadra; In Sweden: Department of Occupational and Environmental Medicine, Lund University Hospital, SE-221 85 Lund, Sweden. Telephone: +46-46-177288, Fax: +46-46-17 36 69; In Nicaragua: Facultad de Ciencias Médicas, Universidad Nacional Autónoma de Nicaragua-Managua (UNAN-Managua), Apartado Postal # 663 Managua, Nicaragua. Telephone: +505-2771850, Fax: +505-2786782 E-mail: steven.cuadra@med.lu.se

ABSTRACT

Objectives: To investigate the occurrence and pattern of injuries among children working at a waste disposal site in Managua, Nicaragua, and in referents from a nearby residential area with similar poor socioeconomic conditions.

Methods: Children aged 6-15 years, working on average since 3 years at the waste disposal site (n=102), and referents (n=101) were interviewed. Only injuries occurring during the last 12 months and causing at least one day of absence from work or from school are reported here. The risk of having an injury, as well as the incidence rates of work and non-work related injuries were estimated using logistic regression and Poisson regression, respectively. Classes of work related injuries (injuries typology) were identified by applying a two-step cluster analysis.

Results: 66 child workers and 20 referents reported at least one injury during the last 12 months (odds ratio 7.4; 95% CI 3.9 to 14). In total, 110 and 22 injuries, respectively, were reported. Among the child workers, most of the injuries occurred at the waste disposal site (n=79; incidence rate of work related injuries 2.2 per 1000 person-days). The most common class of work related injuries included open wounds, which affected feet or lower extremities, and caused between 4 and 13 days lost (n=27; 34%). Also, fractures or dislocations which affected lower or upper extremities, and caused from 1 week up to 2 months of lost work (n=9; 11%) were observed. Moreover, seven (9 %) of the work related injuries resulted in persisting functional impairment or pain, i.e. approximately 0.07 per working year.

Conclusion: The risk of having a work related injury in these child workers is high, with direct impact on the child’s present and future health status, school attendance and on family income. Still our study most likely underestimates the true risk, as only presently active child workers were included.

Keywords: Injuries; children; occupations; waste management; Nicaragua
INTRODUCTION

The International Labour Office (ILO) estimated that, globally, around 211 million children between 5 and 14 years were working in year 2000. Among those, 206 million were living in developing countries. In Central America and the Dominican Republic region there are about 2.4 million children who are presently working, representing 17% of all children aged 5-15 years in the region. About 80% of them are engaged in working activities which are prohibited for children by national legislation or international conventions due to their hazardous nature.

In Nicaragua, it has been estimated from data of the National Child and Adolescents Labour Survey (ENTIA 2000) that 250,000 children aged 5-17 years were working in year 2000. Of these, 37% began working before the age of 10, and 34-68% were involved in hazardous work. Child workers are exposed to a variety of hazards, e.g., dangerous machinery, falling objects, chemicals, abusive employers, which may seriously damage their health. Injuries constitute one of the greatest threats. Based on data from a large national survey in a developing country ILO estimated that 24% of all child workers had suffered at least one injury during their working life, out of which 3% stopped work permanently due to work related injuries (WRIs), and 50% were obliged to do it temporarily. In Nicaragua, ENTIA 2000 estimated that about 14% of the child workers had suffered WRIs.

Recently, concern has risen in the Central American region regarding the hazards for child workers scavenging at waste disposal sites. These include the environmental conditions in which the work is carried out, the exposure to environmental contaminants and hazardous chemicals, and the many social problems related to human survival in places where municipal wastes are deposited. Thousands of children and adults are working at the main urban waste disposal sites in the Latin American countries.

In Managua, the capital of Nicaragua, the municipal domestic and industrial waste disposal site “La Chureca” is located on the south shore of lake Xolotlán, covering an
area of 7 km\(^2\). Approximately 1000 persons, of which more than 50\% are children under age 18, work at the waste disposal site and some of them also live there. (12) Recollection, classification, selling, storing, and cleaning of recyclable waste are the most common activities. Children usually involved in more than one activity, most frequently handling glass, metals, and plastic. Often, the material is stored at home. Recollection of food from the waste disposal site for self-consumption has also been reported. A thick cloud of smoke covers the area since the waste is burned to retrieve iron and other materials. The waste is not compressed, the sun is intense, and a constant breeze from the lake sweeps the area. Thus, substantial amounts of airborne dust are generated. Working at the waste disposal site is considered as one of the worst form of child labour in Nicaragua (3).

The aim of the present study was to investigate the injury occurrence and pattern among children working at the waste disposal site in Managua, and in referents from a nearby residential area with similar poor socioeconomic conditions. This study was part of a larger research project that includes assessment of exposure to heavy metals, persistent organic pollutants as well as exposure to air contaminants and respiratory health.

**MATERIAL AND METHOD**

**Study population and sampling**

In 2002 about 570 children under 18 years were estimated to be working at the waste disposal site. (12) The study and reference groups were established with the help of a local non-governmental organization (NGO) working with child labour eradication programs, Centro Dos Generaciones. This NGO attended children that had a family and regularly worked at the waste disposal site (n= 438) through its community program. (14) Using the register for this program all current child workers were identified who: a) had worked at the waste disposal site for at least one year, b) were of age 6-15 years, and c) lived at the waste disposal site or in a neighbourhood nearby, Acahualinca (n= 117). Additionally, by consulting the student register at the local public primary school and with the help of Centro Dos Generaciones, a list was elaborated of all children presently attending the local primary school in Acahualinca,
aged 6-15 years, who lived in Acahualinca and had never worked at the waste disposal site (n=150). All of them were invited to participate in the study.

The participation rate was high (n=102; 87 %) for the child workers at the waste disposal site (study group). Among those, 60 children lived inside the waste disposal site and 42 children lived in the Acahualinca area. The participation rate was lower (n= 101; 67%) for children in the reference group. The field work was carried out in June 2002. The Ethic’s committees at Lund University and The National Autonomous University of Nicaragua-Managua (UNAN Managua) approved the study protocol, and a written informed consent was obtained from the participants and guardians.

**Data collection**

Trained staff interviewed study participants using a structured questionnaire. The interview took place at the local office of Centro Dos Generaciones. Not only was this a place that was familiar to all children, but members of the staff had been working with the local community for many years; thus a secure atmosphere was created. The duration of the interview ranged between 30 and 60 minutes. For children younger than 10 years help from the child’s parents was required, otherwise children attended the interview in private. All interviewers (n=5) interviewed both child workers and referents.

**The questionnaire**

*Background*

Detailed information on demographic characteristics, occupation, and common daily activities was collected from all children. Also, information on duration of residency at the present site, and supply of basic services such as water and electricity was obtained. For children working at the waste disposal site information on work history (age of onset of work, years worked, current working hours per day, working days per week, present and previous working sites, type of activities at the waste disposal site, and other types of work activities elsewhere) was further enquired.
**Self-reported injury**

Children were asked to recall all events that caused injury of any kind during the past 12 months, leading to at least one day of absence from work or school, excluding the day of the event. This is our definition of injury event.

The interview consisted of a narrative description of each such occasion from the child, which was recorded by the interviewer, followed by a child-oriented injury characterization by use of a check-list questionnaire based on recommendations by the International Labour Organization (ILO). Content analysis of the descriptions was performed to determine, for each injury, where the injury event occurred (place), what the child was doing at the specific moment of the injury event (direct injury related activity), and how the injury happened (mode of injury). The check list collected information on type of injury, primary causal agent, injured body part, number of days of absence from work or school, and persistent functional impairment or disability related to the injury (yes/no). Regular check-ups with all interviewers were performed during the fieldwork period. For description of variables and categories included in the questionnaire see tables 2 and 3.

**Data analysis**

**Risk estimation**

In a first step, we conducted a descriptive analysis where the unit of analysis was the individual child. The risk of having an injury was estimated using odd ratios (OR) and 95% confidence intervals (95% CI) calculated by logistic regression (SPSS for Windows version 12.0.1).

In a second step, injury incidence rates (IR), rate ratios (RR) and 95% confidence intervals (95% CI) were estimated for child workers and referents by Poisson regression (EGRET for Windows version 2.0). Each child was considered to be under risk for 12 months, i.e. 365 days. However, for the child workers the number of days that the child was out of work due to the injury was subtracted. Incidence rates for work related injuries and non-work related injuries were calculated separately, classified as follows:
a) Work related injury (WRI): any personal injury, resulting from an event occurred at the work place including acts of violence (15,16).

b) Non-work related injury (Non-WRI): any personal injury, resulting from an event occurring out of the work place, not linked with the main occupational activities. Injuries related with domestic activities at home were included in this category.

We considered age and sex as potential confounders; in internal comparisons among the child workers work hours and school attendance were also considered. The change-in-estimate-method suggested by Greenland (17) was used, with 10% change required for inclusion and 5% change for exclusion. We found that none of the potential confounders changed the effect estimate by >10%. Thus, only crude estimates are reported.

Classification of work related injuries (WRIs)

In order to classify WRIs into homogenous groups of injury typology (classes) a two-step cluster analysis was performed (SPSS for Windows 12.0.1). Based on previously proposed theoretical frames for injury classification (5,16), only those variables related to the injured person were considered for the identification of classes. The distributions of those variables related with the sequences of the events (injury event descriptors) are described after regarding the identified classes (see table 3), and were not included within the two-step cluster analysis since they show a high level of agreement.

The variables included within the cluster analysis were: type of injury, body part injured, and lost workdays (categorized; used as an indicator of the severity of the injury). When more than one type of injury was reported from a single event, the most severe type of injury and the injured body part related to it (Table 3) was determined based on the child’s own perception as expressed during the interview. The final classification of those variables that were used in the cluster analysis was performed by one person (S N Cuadra), using all information encoded in the interview forms. Since the cluster analysis works best on large groups, the variables representing type of injury and injured body part were aggregated. Thus, for type of injury fractures, luxation/subluxation, traumatic amputation, and internal injuries were all considered
as “traumas”, whereas burns, infections, heatstroke, and other injuries were grouped as “others”. With respect to injured body part, arms, hands, and fingers were all considered “upper extremities”, whereas legs, feet, and toes were considered “lower extremities.” Injuries to neck and spine, back, trunk (including waist and internal organs), and other zones were regarded as “multiple zones” (see table 3).

For the two-step cluster analysis, SPSS uses the agglomerative hierarchical clustering approach. As a measure of similarity between cases (injuries) the log-likelihood distance was selected since this can handle both categorical and continuous variables. The cases were first pre-clustered into small homogenous sub-clusters. The obtained sub-clusters where then regrouped into the final number of clusters. The number of clusters was automatically selected by the statistical software, which also performed a membership assignment (each case was linked to a single cluster). A detailed description of the procedure has been published elsewhere.(18) Additionally, variables that significantly contributed to the cluster formation were identified by estimating the Pearson chi-square as measure of the importance of the categorical variables. For a variable to be considered significant, its Pearson Chi-Square statistic must exceed the critical value.

RESULTS

Child characteristics
The characteristics of the 102 children working at waste disposal site and the 101 referents are described in Table 1. Most of the children had been living in their current residential area for almost their whole life. Almost all children under age 12 attended school, 93% of the child workers at the waste disposal site and 96% of the referent children (not in table). Three out of four children reported that they had domestic chores. Eleven referent children reported that they sometimes worked outside home, mostly irregularly, selling fruit or small goods, washing cars, or helping their parents in the family business.

Work at the waste disposal site
The child workers commonly started to work at a low age (median age of onset 7 years), and were working a median of 4 hours a day, and a median of 4 days a week.
Most of the children worked in the early mornings; however, some of them also worked in the evenings or at nights. The work tasks consisted mainly of recollection (97%), classification (73%), selling (59%), storing (59%), and cleaning of waste (31%). Most of the children performed more than one of these activities. Glass, metal, plastic, and paper were the most common materials handled. Also recollection of food at the waste disposal site for self-consumption was reported. Furthermore, 40% of the children reported that materials recollected at the waste disposal site were stored in their home, mainly metals, plastic, and glass (data not presented in tables).

**Injury occurrence**

Sixty-six child workers and 20 referents had suffered injuries causing at least one day of absence from school or work, apart from the day of the event, during the past 12 months. Thus, the child workers had a seven-fold increased risk of being injured (OR= 7.4, 95% CI 3.9 to 14).

Multiple injuries were common in the child workers. Twenty-seven children working at the waste disposal site (45% of those injured) but only one referent reported more than one injury, leading to a total of 110 and 22 reported injuries in the study and reference group, respectively. Forty-nine child workers reported 79 WRIs, corresponding to an incidence rate of 2.2 per 1000 person-days (Figure 1). No WRIs were reported in the referent group.

Material handling (63%), vehicles (11%), working area condition (11%), and violence (6%) were the most frequent causes of WRIs among child workers (Table 2). Most of these work injuries, around 60%, resulted in less than one week of absence from work or school. For 10% of the WRIs more than one month of absence was reported. Seven (9%) of the reported WRIs resulted in persisting functional impairment or pain, i.e. approximately 0.07 per working year.

We observed neither gender or age differences in the occurrence of WRIs, nor an influence of the number of working hours. The incidence of Non-WRI was similar in the two groups, 0.8 and 0.6 per 1000 person-days, respectively (Figure 1). Also, the types of injuries were similar (Table 2). In the referent group the injuries occurred when children were helping in domestic activities or playing with other children. In
the child workers injuries also happened on the way to and from work, and when they were handling goods collected at the waste disposal site but stored at home for personal uses, e.g. wood or electric devices. In both groups the severity of the non-WRIs was comparable, with very few cases of severe injuries.

**Injury classes for work related injuries (WRIs) in child workers**

The two-step cluster analysis revealed five main injury patterns (classes). The distribution of the injuries within each class is shown in Table 3. The variables that contributed significantly to the formation of each class are marked in italics below. The name given to each class reflects the most significant categories (descriptors) around which each class was formed.

**Class 1:** *Open wound, affecting lower extremities, causing 4-13 workdays lost.*

This class is the largest (n=27; 34%), and covers WRIs that occurred when children were collecting waste at the waste disposal site by hand or using simple tools, stepping on or handling the waste material. Thus the most significant agent is the waste itself (glass, metal, plastic, etc.). Feet and lower extremities were usually the affected part of the body. The severity was moderate, expressed as lost workdays (around a week).

**Class 2:** *Open wound, affecting upper extremities, causing 4-13 workdays lost.*

Class 2 is characterized by open wound injuries in the hands and upper extremities (n=14; 18%). These occurred most typically when children were collecting waste, and the common agent of injury was the handled material, as in the previous injury class. The severity was moderate, expressed by lost workdays (around a week).

**Class 3:** *Traumas, affecting lower and upper extremities, causing from 1 week up to 2 months of lost work*

This class represents the most severe kind of injury, affecting mostly upper and lower extremities, (n=9; 11%). Children spend several weeks in order to come back to work, thus the severity is high. This kind of injury occurred when children were waiting at the entrance of the waste disposal site for trucks which bring the waste material and jumping jumped on the truck to seek material within the garbage before the truck
reached its final disposal site. Children may be crushed by these truck or fall down from it when it is still moving.

**Class 4: Superficial injuries causing less than 3 lost workdays.**
This class represent the least severe injuries (n=11; 14%). This kind of injury could be produced by several modes of injury, including also fall at the same level when playing with other children, and violence from another person.

**Class 5: Open wound, affecting lower extremities, causing less than 3 lost workdays.**
This class is similar to class one, but with low severity (n=14, 18%).

**DISCUSSION**

In Nicaragua, the minimum age for work is 14 years, according to the national legislation, but it has been estimated that almost half of all working children in the country are under this age, and one out of three has started before age 10.\(^{(3)}\) The child workers at the waste disposal site start at even younger age (median 7 years). In families living and working at the waste disposal site, children spend their days at the waste disposal site from early infancy (Photo 1), gradually taking part in the work activities. Thus, when some children considered themselves as workers at the waste disposal site since the age of two, it indeed reflects their reality. Thus the life and development of the children is affected seriously from a very early age.

The overall injury risk in child workers at the waste disposal site was very high, with injuries directly related to work activities contributing the most. The incidence rate observed in our study group approximately means that every week one child out of 100 had an injury that caused absence from work for one day or more. The proportion of child workers at the waste disposal site reporting any WRI is much higher than the estimated proportion for other child workers expressed in contemporary reports. The International Programme on the Elimination of Child Labour (IPEC-ILO) reported from one large national survey conducted in a developing country \(^{(7)}\) that 24% of children working have ever suffered a WRI during their working life. In Nicaragua a recent survey estimated that 14 % of children working have suffered at least one WRI during their working life.\(^{(3)}\) In contrast, 48% of our child workers at the waste
disposal site reported at least one WRI during the last 12 months and as many as 63% reported a WRI during the last 3 years. This is in line with findings from Guatemala, where 82% of children working at the main waste disposal in Guatemala City reported that they had suffered open wounds and superficial injuries during their working life.\textsuperscript{19,20}

However, for several reasons, our study most likely underestimates the true risk for child workers at the waste disposal site. Firstly, our study is a cross-sectional study of active child workers with a median of 3 years duration of work; thus a healthy worker selection is likely to be present, especially for the most severe injuries. Secondly, all children enrolled were living with a family. Those children whose primary support is not a family or a family substitute, or whose behaviour is at odds with community norms, e.g. street children and drug abusers, may be engaged in more dangerous work activities at the waste disposal site, and are likely to be more vulnerable \textsuperscript{21} and thus have a greater risk to suffer an injury.

The child workers at the waste disposal site included in the study represent the great majority of all child workers living with a family in the selected age category. They were compared with referents living in an area nearby the waste disposal site, with the intention of finding a close similarity in socioeconomic conditions. Thus, all children had a family. Among referents, 11% reported informal work outside their home, a figure that is similar to overall estimates for Nicaraguan children.\textsuperscript{3} The body mass index (BMI), blood iron content and blood lipid concentration in the child workers and the referents were comparable, indicating similar nutritional status (own data). School attendance was very high in both groups, even higher than for other urban Nicaraguan children.\textsuperscript{3} This is explained by the recruitment of child workers at the waste disposal site through Centro Dos Generaciones, which has a special educational programme for child workers based on the concept that access to education is the most powerful tool to break the cycle of poverty \textsuperscript{12,22} and by the recruitment of referents using school registers. The participation rate was lower in referents than in child workers at the waste disposal site. Our impression during the fieldwork was that the main reason for non-participation among referents was the blood-sampling which constituted another part of the study programme, whereas the child workers at the waste disposal site and parents were more concerned about the chemical hazards.
investigated, and thus more prone to participate. Thus, we do not expect that the loss of participants among referents is differential with regard to injury prevalence.

The risk for recall bias has to be considered. Thus, information on work, school attendance, and other non-occupational activities provided by children or their parents was corroborated with current records from the local institutions. In the interview situation, focus was on all injuries, not only WRI. The occurrence and typology of Non-WRIs was similar in the study and referent groups. In both groups there were only one or two individuals that reported more than one Non-WRI. This speaks against overreporting of injuries among child workers at the waste disposal site. Also, it speaks against an intrinsic injury-prone behaviour in child workers at the waste disposal site.

In our study, most of the injuries that we classified as Non-WRIs in both the study and reference groups occurred at home or in the residential area. It could be argued that some of these injuries were in reality work-related – those happening going to the workplace, and those happening when the children were doing household chores. The fact that traffic accidents were seldom reported is explained by neighbourhood characteristics - a very poor community (22), lacking infrastructure and roads. Thus, vehicle traffic intensity is very low.

Even if it can be agreed that child labour on waste disposal sites is a serious violation of all national and international commitments concerning the human rights of children, and that such work should be abolished, in a short perspective it is also necessary to face the question if there are feasible strategies for injury prevention. A prerequisite for such prevention is the identification of characteristics of both the injuries and their circumstances of occurrence.(23-26) Different hierarchical classification approaches have been used previously for occupational settings (27), and for investigation of childhood injuries.(28-32) A cluster analysis aims to find homogenous groups, whose characteristics give the possibility to identify possible preventive methods.

Class 1 and class 5 point to a particular part of the body (lower extremities, mostly feet) and a specific types of injury (open wounds and superficial injuries), with low or
moderate severity. These two classes accounted for almost 50% of all investigated injuries in these children. These injuries occurred mostly during the moment when children were collecting and classifying the material. Class 2 shares a similar pattern, but is affecting upper extremities and hands. Thus, these three classes together counted for 70% of all injuries. A crude calculation, assuming a mean absence of 7 day from work and school per injury, yields that if these classes of injuries could be totally avoided, the absence from work and school would be reduced by more than 500 days per year in 100 workers. A total reduction is not realistic, but simple protective measures can reduce the risk for injury. Today, many of the children wear no shoes at all during their work, and no one has access to gloves.

The class of injury that includes the most severe injuries (class 4) reflects a very dangerous situation (Photo 2). In order to be able to have access to saleable garbage children have to risk their life. They wait for the municipal garbage trucks at the entrance of the waste disposal site, and jump onto the moving truck in order to collect the so called best material. Moreover, most of the time they have to compete with adults to have this opportunity. Then, the risk is not only the risk of having an accident, but also to suffer violence. Children that suffer this class of injury usually are absent from work and school for up to 2 months, which might cause the loss of the whole scholar year. Also, a long absence from work will have substantial impact on the family income, and thus also on the material situation for the child, as children working at the waste disposal site may contribute as much as 30% of the monthly family income. (12,22) Our study in active workers underestimates the true risk in this situation, and it is obvious that also more serious accidents should be investigated.

As in many other countries, labour in agriculture, forestry, fishing, mining and quarrying, manufacturing, transport and commerce/warehousing has been identified as conferring the greatest risk for working children in Nicaragua. (3) Quantitative data on the health effects from such extreme working situations as work at waste disposal sites has hitherto been scarce, or absent. Clearly, there is insufficient awareness of the high risk in this form of child labour, which may seriously endanger not only the physical, but also the emotional, intellectual and social development of the children.
ACKNOWLEDGEMENTS

We gratefully acknowledge the cooperation of the children participating in the study, the staffs from “Centro Dos Generaciones” and “Chateles Project”, Adolfo Salinas from the Faculty of Medicine, UNAN Managua, the authorities from the local primary school, and the local health center. Also we acknowledge the support from Professor Lucie Laflamme who gave us valuable advices on constructing the injury typology. The personnel from the regional office of the ILO/IPEC Programme for Central America, Panama, Dominican Republic, Haiti and Mexico generously provided access to all the background documentation. The study was funded by the Swedish International Agency for Research Cooperation with Developing countries, SAREC, within the frame of a multidisciplinary co-operation program between Lund University and the National Autonomous University of Nicaragua-Managua (UNAN-Managua).
REFERENCES


7  Ashagrie K. Statistic on working children and hazardous child labour in brief. 
Geneva: International Labour Office, Available from: 

8  Carranza AC, Zelaya L, Iglesias S. El Salvador, trabajo Infantil en los 
basureros: Una evaluación rápida [El Salvador, child labour at waste disposal 
sites: a rapid assessment] [In Spanish]. Geneva: International Labour Office 
(ILO), International Programme on the Elimination of Child Labour (IPEC); 
2002. Available from 
[Accessed May 23, 2005]

9  García F, Duque V. Guatemala. Child labour in garbage dumps: A rapid 
Programme on the Elimination of Child Labour (IPEC); 2002. Available from 
[Accessed September 1, 2005]

10 International Programme on the Elimination of Child Labour. Estudio de línea 
de base. Trabajo infantil en el botadero de basura de Tegucigalpa, Honduras 
[Base line study. Child labour at Tegucigalpa waste disposal site, Honduras] 
[In Spanish]. San José, Costa Rica: International Labour Office (ILO), 
International Programme on the Elimination of Child Labour (IPEC); 2004. 
Available from http://www.oit.org.pe/ipec/documentos/tegucigalpa.pdf and 

11 International Programme on the Elimination of Child Labour. Estudio de línea 
de base. Trabajo infantil en el botadero de basura de San Pedro Sula, Honduras 
[Base line study. Child labour at the San Pedro waste disposal site, Honduras]

16

12 IDESO/UCA. Estudio de línea basal: Programa eliminación progresiva del trabajo infantil en el basurero de Managua La Chureca” [Base line study: Program on progressive elimination of child labour at Managua city dump La Chureca”] [In Spanish]. Managua: Instituto de Encuestas y Sondeos de Opinión-Universidad Centro Americana (IDESO/UCA); 2001.


14 Vargas J. Listado de Ninos, Ninas y Adolescentes Trabajadores (NATs) del basuero municipal de Managua, La Chureca [Register of child workers at the municipal waste disposal site, La Chureca] [In Spanish]. Managua: Centro de Promoción de la Juventud y la Infancia "Dos Generaciones": Programa Comunitario Acahualinca; 2002.


22 Borge & Asociados. Estudio diagnóstico sobre la generación de ingresos alternativos o complementarios, oportunidades y potencialidades de y para los niños de Acahualinca [Diagnostic study on generation of alternative or complementary incomes, opportunities, and potentialities of and for children from Acahualinca] [In Spanish]. Managua: Centro Nicaraguense de Promoción de la Juventud y La Infancia "Dos Generaciones"; 2000.

23 Heath ED. Identifying those worker populations that are at higher levels of risk. *Am Ind Hyg Assoc J* 1991;52:A211-2.


<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Children working at the waste disposal site</th>
<th>Children not working at the waste disposal site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
<td>Not Injured</td>
</tr>
<tr>
<td>N</td>
<td>66</td>
<td>36</td>
</tr>
<tr>
<td>Sex†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>41 (62)</td>
<td>18 (50)</td>
</tr>
<tr>
<td>Female</td>
<td>25 (38)</td>
<td>18 (50)</td>
</tr>
<tr>
<td>Age (years)‡§</td>
<td>13 (6-15)</td>
<td>11.5 (6-15)</td>
</tr>
<tr>
<td>Attending school†</td>
<td>55 (83)</td>
<td>32 (89)</td>
</tr>
<tr>
<td>Domestic activity†</td>
<td>47 (71)</td>
<td>27 (75)</td>
</tr>
<tr>
<td>Duration of residency‡</td>
<td>8 (2-15)</td>
<td>9 (2-15)</td>
</tr>
<tr>
<td>Work at the waste disposal site§</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of onset</td>
<td>7 (2-13)</td>
<td>7.5 (2-13)</td>
</tr>
<tr>
<td>Years worked</td>
<td>3 (1-12)</td>
<td>2.5 (1-10)</td>
</tr>
<tr>
<td>Hours/day</td>
<td>4 (1-12)</td>
<td>4 (1-12)</td>
</tr>
<tr>
<td>Days/week</td>
<td>5 (1-7)</td>
<td>3 (1-6)</td>
</tr>
</tbody>
</table>

*Experience of at least one injury of any kind during the past 12 months, causing absence of at least one day from school or work apart from the day of the event

†n (%)  
‡Median and range  
§Age was missing for 1 child
Table 2: Description of work related injuries and non-work related injuries in children working at Managua waste disposal site, “La Chureca” and in referents.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Children working at the waste disposal site</th>
<th>Children not working at the waste disposal site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WRI</td>
<td>Non-WRI</td>
</tr>
<tr>
<td>N</td>
<td>79</td>
<td>29</td>
</tr>
<tr>
<td>Age</td>
<td>14 (6-15)</td>
<td>12 (6-15)</td>
</tr>
<tr>
<td>Sex</td>
<td>55 (70)</td>
<td>14 (48)</td>
</tr>
<tr>
<td></td>
<td>24 (30)</td>
<td>15 (52)</td>
</tr>
<tr>
<td>Type of injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open wound</td>
<td>57 (72)</td>
<td>21 (72)</td>
</tr>
<tr>
<td>Superficial Injury</td>
<td>30 (38)</td>
<td>12 (41)</td>
</tr>
<tr>
<td>Trauma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fractures</td>
<td>8 (10)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Luxation (dislocation) or subluxation</td>
<td>7 (9)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Traumatic amputation</td>
<td>2 (3)</td>
<td>0</td>
</tr>
<tr>
<td>Internal injuries</td>
<td>1 (1)</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burns</td>
<td>5 (6)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Infections</td>
<td>14 (18)</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Heatstroke</td>
<td>2 (3)</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>2 (3)</td>
<td>0</td>
</tr>
<tr>
<td>Agent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucks/others vehicles</td>
<td>9 (11)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Transport of material</td>
<td>5 (63)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Materials handling</td>
<td>50 (63)</td>
<td>11 (38)</td>
</tr>
<tr>
<td>Place condition (working area condition)</td>
<td>9 (11)</td>
<td>10 (34)</td>
</tr>
<tr>
<td>Animals</td>
<td>1 (1)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Violence by other person (minors)</td>
<td>4 (5)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Violence by other person (adults)</td>
<td>1 (1)</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Injured body part</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>13 (18)</td>
<td>6 (21)</td>
</tr>
<tr>
<td>Upper extremities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper extremities excluding hands</td>
<td>10 (13)</td>
<td>7 (24)</td>
</tr>
<tr>
<td>Hands, including fingers</td>
<td>12 (15)</td>
<td>4 (14)</td>
</tr>
<tr>
<td>Lower extremities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower extremities excluding feet</td>
<td>19 (24.1)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Feet, including toes</td>
<td>40 (41)</td>
<td>12 (42)</td>
</tr>
<tr>
<td>Multiple zones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck and spine</td>
<td>2 (3)</td>
<td>0</td>
</tr>
<tr>
<td>Back including hips and spine</td>
<td>9 (11)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Trunk including waist and internal organs</td>
<td>1 (1)</td>
<td>0</td>
</tr>
<tr>
<td>Other zone</td>
<td>7 (9)</td>
<td>3 (10)</td>
</tr>
<tr>
<td>Absent days from school / work apart from the day of the event</td>
<td>28 (35)</td>
<td>14 (48)</td>
</tr>
<tr>
<td>1-3 days</td>
<td>19 (24)</td>
<td>4 (14)</td>
</tr>
<tr>
<td>7-13 days</td>
<td>17 (21)</td>
<td>3 (10)</td>
</tr>
<tr>
<td>14-29 days</td>
<td>7 (9)</td>
<td>5 (17)</td>
</tr>
<tr>
<td>1-2 month</td>
<td>8 (10)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>≥3 months</td>
<td>0</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Persisting functional impairment / pain§</td>
<td>70 (89)</td>
<td>22 (76)</td>
</tr>
<tr>
<td>No</td>
<td>7 (9)</td>
<td>6 (21)</td>
</tr>
</tbody>
</table>

* Work-related injuries (at the waste disposal site)
† Non-work related injuries (at home, residential area or school)
‡ Multiple types of injury and multiple injured body part related to the same injury event were reported by almost all children. Thus the percentage expressed in these categories is calculated based on the total number of injuries, therefore the sum of percentages is greater than 100%.
§ Information on persisting functional impairment or pain was missing for two WRI and one Non-WRI among children working at the waste disposal site.
Table 3: Composition of the injury classes, obtained by the two-step cluster analysis, regarding variables including in the analysis and injury event descriptors.

<table>
<thead>
<tr>
<th>Variables included in the two-step cluster analysisa</th>
<th>Class 1 n=25</th>
<th>Class 2 n=16</th>
<th>Class 2 n=13</th>
<th>Class 3 n=11</th>
<th>Class 5 n=14</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of injury</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open wound</td>
<td>22 (87)</td>
<td>16 (100)</td>
<td>1 (8)</td>
<td>0</td>
<td>14 (100)</td>
</tr>
<tr>
<td>Superficial injury</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11 (100)</td>
<td>0</td>
</tr>
<tr>
<td>Trauma†</td>
<td>1 (4)</td>
<td>0</td>
<td>11 (92)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other (mostly burning)</td>
<td>3 (12)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Part of body injured</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower extremities§</td>
<td>26 (100)</td>
<td>0</td>
<td>2 (17)</td>
<td>4 (36)</td>
<td>14 (100)</td>
</tr>
<tr>
<td>Upper extremities§</td>
<td>0</td>
<td>10 (63)</td>
<td>5 (42)</td>
<td>1 (9)</td>
<td>0</td>
</tr>
<tr>
<td>Multiples zones¶</td>
<td>0</td>
<td>2 (13)</td>
<td>5 (42)</td>
<td>5 (46)</td>
<td>0</td>
</tr>
<tr>
<td>Head</td>
<td>0</td>
<td>4 (25)</td>
<td>0</td>
<td>1 (9)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Absent days from work/school</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-3 days</td>
<td>0</td>
<td>3 (19)</td>
<td>0</td>
<td>11 (100)</td>
<td>14 (100)</td>
</tr>
<tr>
<td>4-6 days</td>
<td>15 (58)</td>
<td>3 (19)</td>
<td>1 (8)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7-13 days</td>
<td>7 (27)</td>
<td>9 (56)</td>
<td>1 (8)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14-29 days</td>
<td>1 (4)</td>
<td>1 (6)</td>
<td>5 (42)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1-2 months</td>
<td>3 (12)</td>
<td>0</td>
<td>5 (42)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Injury event descriptor

<table>
<thead>
<tr>
<th>Variables related with sequence of the events</th>
<th>Class 1 n=25</th>
<th>Class 2 n=16</th>
<th>Class 2 n=13</th>
<th>Class 3 n=11</th>
<th>Class 5 n=14</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collecting material (waste handling)</td>
<td>20 (77)</td>
<td>12 (75)</td>
<td>2 (17)</td>
<td>9 (82)</td>
<td>13 (93)</td>
</tr>
<tr>
<td>Waiting for the incoming waste-transporting truck</td>
<td>0</td>
<td>1 (6)</td>
<td>3 (25)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jumping onto the moving trucks (to collect material)</td>
<td>1 (4)</td>
<td>1 (6)</td>
<td>4 (33)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Carrying waste (to home or another place)/(manual transportation)</td>
<td>4 (15)</td>
<td>1 (6)</td>
<td>2 (17)</td>
<td>1 (9)</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Classifying and cleaning collected material (waste)</td>
<td>1 (6)</td>
<td>1 (8)</td>
<td>1 (9)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Playing with other children</td>
<td>1 (4)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Agency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td>1 (4)</td>
<td>1 (6)</td>
<td>7 (58)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Waste (material)</td>
<td>21 (81)</td>
<td>11 (68)</td>
<td>4 (33)</td>
<td>5 (46)</td>
<td>14 (100)</td>
</tr>
<tr>
<td>Place condition (working area condition)</td>
<td>4 (15)</td>
<td>2 (13)</td>
<td>0</td>
<td>3 (27)</td>
<td>0</td>
</tr>
<tr>
<td>Animals</td>
<td>0</td>
<td>0</td>
<td>1 (8)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other person (minors)</td>
<td>0</td>
<td>2 (13)</td>
<td>0</td>
<td>2 (18)</td>
<td>0</td>
</tr>
<tr>
<td>Other person (adults)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1 (9)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mode of injury</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit by trucks or other vehicles</td>
<td>0</td>
<td>0</td>
<td>5 (42)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Violence (Hit or hurt by other person)</td>
<td>0</td>
<td>2 (13)</td>
<td>0</td>
<td>3 (27)</td>
<td>0</td>
</tr>
<tr>
<td>Hit or hurt by animals</td>
<td>0</td>
<td>0</td>
<td>1 (8)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Falls (at the same level)</td>
<td>4 (15)</td>
<td>2 (13)</td>
<td>0</td>
<td>3 (27)</td>
<td>0</td>
</tr>
<tr>
<td>Struck by falling objects during handling</td>
<td>1 (6.3)</td>
<td>1 (6.3)</td>
<td>2 (17)</td>
<td>1 (9)</td>
<td>0</td>
</tr>
<tr>
<td>Stepping on, or handling material</td>
<td>21 (81)</td>
<td>10 (62.5)</td>
<td>2 (17)</td>
<td>4 (36)</td>
<td>14 (100)</td>
</tr>
<tr>
<td>Exposure to or contact with extreme temperature</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Falls of person from heights (vehicles)</td>
<td>1 (4)</td>
<td>1 (6.3)</td>
<td>2 (17)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

---

* Each work related injury event was classified according to the most serious type of injury and the part of the body affected by that injury
†Fractures, luxation/sub-luxation, traumatic amputation and internal injuries
‡Legs, feet, and toes
§Arms, hands, and fingers
¶Neck and spine, back, trunk (including waist and internal organs), and other zones
Figure 1: Injury incidence rate in children working at Managua waste disposal site, “La Chureca” and in referents. The rate ratios (RR) and 95% CI were calculated by Poisson regression.

Photo 1: Not only teenagers but also younger children are working at the waste disposal site, some of them since early childhood. (Photo by Danilo Hernández)
Photo 2: Child workers usually compete with adults in order to get access to the collector truck and look for what they call “the best garbage”. This is a common scene at the waste disposal sites. Workers express that many accidents are occurring every month, but these accidents are not officially reported to the local health authorities. (Photo by Danilo Hernández)