National Health and Nutrition Examination Survey

August 2021-August 2023 Data Documentation, Codebook, and Frequencies

Lead, Cadmium, Total Mercury, Selenium, & Manganese – Blood (PBCD_L)

Data File: PBCD_L.xpt

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Component Description

Lead

Lead is a known environmental toxin that has been shown to affect deleteriously the nervous, hematopoietic, endocrine, renal, and reproductive systems. In young children, lead exposure is a particular hazard because children more readily absorb lead than adults, and children's developing nervous systems also make them more susceptible to the effects of lead. The primary sources of exposure for children are lead-laden paint chips and dust as a result of deteriorating lead-based paint. The risk for lead exposure is disproportionately higher for children who are poor, non-Hispanic black, living in large metropolitan areas, or living in older housing. Among adults, the most common high exposure sources are occupational. Blood lead levels measured in previous NHANES cycles have been the cornerstone of lead exposure surveillance in the U.S. The data have been used to document the burden and dramatic decline of elevated blood lead levels, to promote the reduction of lead use, and to help to redefine national lead poisoning prevention guidelines, standards, and abatement activities.

Cadmium

Blood cadmium reflects both recent and cumulative exposures. Cadmium is absorbed via inhalation and ingestion. Occupational exposure is the most common cause of elevated cadmium levels. Inhalation of cigarette smoke is a predominant source of exposure in smokers whose blood cadmium levels have been observed to be about twice as high compared to nonsmokers. For nonsmokers who are not exposed to cadmium in the workplace, ingestion through food is the largest source of exposure. With chronic exposure, cadmium accumulates in the liver and kidneys where it is bound to metallothionein, an inducible metal binding protein. The kidney is a critical target and shows the earliest sign of cadmium toxicity. Cadmium can produce lung, pituitary gland and kidney tumors in animals and has been associated with lung cancer in humans in occupational epidemiologic studies. Both International Agency for Research on Cancer (IARC) and National Toxicology Program (NTP) consider cadmium a human carcinogen.

Manganese

The greatest demand for manganese is for the production of iron and steel. In addition, it is a key component of low-cost stainless steel and certain aluminum alloys. At low concentrations, it is used to decolorize glass, while at higher concentrations; it is used to make violet-colored glass. Manganese dioxide, besides being a useful pigment, is a catalyst and a component of certain dry cell batteries. Potassium permanganate is a potent oxidizer and disinfectant. Manganese (in the form of manganese ions) is an essential trace nutrient in all known forms of life. On the other hand, excess manganese is toxic.

Total Mercury

Uncertainties exist regarding levels of exposure to methyl mercury from fish consumption and potential health effects resulting from this exposure. Past estimates of exposure to methyl mercury have been obtained from results of food consumption surveys and measures of methyl mercury in fish. Measures of a biomarker of exposure are needed for improved exposure assessments. Blood mercury levels will be assessed in two subpopulations particularly vulnerable to the health effects from mercury exposure: children 1-5 years old and women of childbearing age. Blood measures of total and inorganic mercury will be important for evaluation of exposure from exposure to mercury in interior latex paints.

Selenium

Selenium salts are toxic in large amounts, but trace amounts are necessary for cellular function in many organisms, including all animals. Selenium is a component of the antioxidant enzymes glutathione peroxidase and thioredoxin reductase (which indirectly reduce certain oxidized molecules in animals and some plants). It is also found in three deiodinase enzymes, which convert one thyroid hormone to another. Selenium requirements in plants differ by species, with some plants requiring relatively large amounts, and others apparently requiring none.

Eligible Sample

Examined participants aged 1 year and older were eligible.

Description of Laboratory Methodology

This method directly measures lead (Pb), cadmium (Cd), total mercury (Hg), manganese (Mn), and selenium (Se) content of whole blood specimens using mass spectrometry after a simple dilution sample preparation step.

During the sample dilution step, a small volume of whole blood is extracted from a larger whole blood patient specimen after the entire specimen is mixed (vortexed) to create a uniform distribution of cellular components. This mixing step is important because some metals (e.g., Pb) are known to be associated mostly with the red blood cells in the specimen and a uniform distribution of this cellular material must be produced before a small volume extracted from the larger specimen will accurately reflect the average metal concentration of all fractions of the larger specimen. Coagulation is the process in which blood forms solid clots from its cellular components. If steps are not taken to prevent this process from occurring, i.e., addition of anti-coagulant reagents such as EDTA in the blood collection tube prior to blood collection, blood will immediately begin to form clots once leaving the body and entering the tube. These clots prevent the uniform distribution of cellular material in the blood specimen even after rigorous mixing, making a representative sub-sample of the larger specimen unattainable. It is important that prior to or during sample preparation the analyst identify any sample having clots or micro-clots (small clots). Clotted samples are not analyzed by this method due to the inhomogeneity concerns (i.e., all results for the sample are processed as “not reportable”).

Dilution of the blood in the sample preparation step prior to analysis is a simple dilution of 1 part sample + 1 part water + 48 parts diluent. The effects of the chemicals in the diluent are to release metals bound to red blood cells making them available for ionization, reduce ionization suppression by the biological matrix, prevent clogging of the sample introduction system pathways by undissolved biological solids, and allow introduction of internal standards to be utilized in the analysis step. Tetramethylammonium hydroxide (TMAH, 0.4% v/v) and Triton X-100TM (0.05%) in the sample diluent solubilizes blood components. Triton X-100TM also helps prevent biological deposits on internal surfaces of the instrument’s sample

introduction system and reduce collection of air bubbles in sample transport tubing. Ammonium pyrrolidine dithiocarbamate (APDC) in the sample diluent (0.01%) aids in solubilizing metals released from the biological matrix. Ethyl alcohol in the sample diluent (1%) aids solubility of blood components and aids in aerosol generation by reduction of the surface tension of the solution. The internal standards, rhodium, iridium, and tellurium, are at a constant concentration in all blanks, calibrators, QC, and samples. Monitoring the instrument signal ratio of a metal to its internal standard allows correction for instrument noise and drift, and sample-to-sample matrix differences.

Liquid samples are introduced into the mass spectrometer through the inductively coupled plasma (ICP) ionization source. The liquid diluted blood sample is forced through a nebulizer, which converts the bulk liquid into small droplets in an argon aerosol. The smaller droplets from the aerosol are selectively passed through the spray chamber by a flowing argon stream into the ICP. By coupling radio-frequency power into flowing argon, plasma is created in which the predominant species are positive argon ions and electrons and has a temperature of 6000-8000 K. The small aerosol droplets pass through a region of the plasma and the thermal energy vaporizes the liquid droplets, atomizes the molecules of the sample and then ionizes the atoms. The ions, along with the argon, enter the mass spectrometer through an interface that separates the ICP (at atmospheric pressure, ~760 torr) from the mass spectrometer (operating at a pressure of 10-5 torr). The ions first pass through a focusing region, then the dynamic reaction cell (DRC), the quadrupole mass filter, and finally are selectively counted in rapid sequence at the detector allowing individual isotopes of an element to be determined.

Generally, the DRC operates in one of two modes. In 'vented' (or 'standard') mode the cell is not pressurized and ions pass through the cell to the quadrupole mass filter unaffected. In 'DRC' mode, the cell is pressurized with a gas for the purpose of causing collisions and/or reactions between the fill gas and the incoming ions. In general, collisions or reactions with the incoming ions selectively occur to either eliminate an interfering ion, change the ion of interest to a new mass, which is free from interference, or collisions between ions in the beam and the DRC gas can focus the ion beam to the middle of the cell and increase the ion signal. In this method, the instrument is operated in DRC mode when analyzing for manganese, mercury, and selenium. For selenium, the DRC is pressurized with methane gas (CH_4, 99.999%) which reduces the signal from $^{40}Ar_2^+$ while allowing the $^{80}Se^+$ ions to pass relatively unaffected through the DRC on toward the analytical quadrupole and detector. Manganese and mercury are both measured when the DRC is pressurized with oxygen gas (O_2, 99.999%). They are analyzed at the same flow rate of oxygen to the DRC cell to avoid lengthening analysis time due to pause delays that would be necessary if different gas flows were used for the two analytes. The oxygen reduces the ion signal from several interfering ions ($^{37}Cl^{18}O^+$, $^{40}Ar^{15}N^+$, $^{38}Ar^{16}O^1H^+$, $^{54}Fe^1H^+$) while allowing the Mn^+ ion stream to pass relatively unaffected through the DRC on toward the analytical quadrupole and detector. In the case of mercury, collisional focusing of the mercury ions occurs, increasing the observed mercury signal at the detector by approximately a factor of two (2x).

Once ions pass through the DRC cell and electrically selected for passage through the analytical quadrupole, electrical signals resulting from the ions striking the discrete dynode detector are processed into digital information that is used to indicate the intensity of the ions. The intensity of ions detected while aspirating an unknown sample is correlated to an elemental concentration through comparison of the analyte: internal standard signal ratio with that obtained when aspirating calibration standards. This method was originally based on the method by Lutz (Lutz et. al., 1991). The DRC portions of the method are based on work published by Tanner (Tanner, et. al., 1999; 2002).

Refer to the Laboratory Method Files section for a detailed description of the laboratory methods used.

There were no changes to the lab equipment or lab site for this component, however there was a change to the lab methods for the August 2021–August 2023 cycle.

Laboratory Method Files

Blood Lead, Cadmium, Total Mercury, Selenium and Manganese (September 2024)

Laboratory Quality Assurance and Monitoring

Whole blood specimens were processed, stored, and shipped to the National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, GA for analysis.

Detailed instructions on specimen collection and processing are discussed in the NHANES Laboratory Procedures Manual (LPM). Vials are stored under appropriate frozen (–30°C) conditions until they are shipped to National Center for Environmental Health for testing.

The NHANES quality assurance and quality control (QA/QC) protocols meet the 1988 Clinical Laboratory Improvement Amendments mandates. Detailed QA/QC instructions are discussed in the NHANES LPM.

Mobile Examination Centers (MECs)

Laboratory team performance is monitored using several techniques. NCHS and contract consultants use a structured competency assessment evaluation during visits to evaluate both the quality of the laboratory work and the QC procedures. Each laboratory staff member is observed for equipment operation, specimen collection and preparation; testing procedures and constructive feedback are given to each staff member. Formal retraining sessions are conducted annually to ensure that required skill levels were maintained.

Analytical Laboratories

NHANES uses several methods to monitor the quality of the analyses performed by the contract laboratories. In the MEC, these methods include performing blind split samples collected on "dry run" sessions. In addition, contract laboratories randomly perform repeat testing on 2% of all specimens.

NCHS developed and distributed a QC protocol for all the contract laboratories, which outlined the use of Westgard rules (Westgard et. al., 1981) when testing NHANES specimens. Progress reports containing any problems encountered during shipping or receipt of specimens, summary statistics for each control pool, QC graphs, instrument calibration, reagents, and any special considerations are submitted to NCHS quarterly. The reports are reviewed for trends or shifts in the data. The laboratories are required to explain any identified areas of concern.

All QC procedures recommended by the manufacturers were followed. Reported results for all assays meet the Division of Environmental Health Laboratory Sciences QA/QC performance criteria for accuracy and precision, similar to the Westgard rules (Caudill, et. al., 2008).

Data Processing and Editing

The data were reviewed. Incomplete data or improbable values were sent to the performing laboratory for confirmation.

Five additional variables were created for this data file. The variables were created using the following formulas:

LBDBCDSI: The analyte cadmium value in µg/L (LBXBCD) was converted to nmol/L (LBDBCDSI) by multiplying LBXBCD by 8.897 (Round 3 decimal points).

LBDBPBSI: The analyte lead value in µg/dL (LBXBPB) was converted to µmol/L (LBDBPBSI) by multiplying LBXBPB by 0.0483 (Round 3 decimal points).

LBDBMNSI: The analyte manganese value in µg/L (LBXBMN) was converted to nmol/L (LBDBMNSI) by multiplying LBXBMN by 18.202 (Round 2 decimal points).

LBDBSESI: The analyte selenium value in µg/L (LBXBSE) was converted to µmol/L (LBDBSESI) by multiplying LBXBSE by 0.0127 (Round 1 decimal points).

LBDTHGSI: The analyte mercury value in µg/L (LBXTHG) was converted to nmol/L (LBDTHGSI) by multiplying LBXTHG by 4.99 (Round 2 decimal points).

Analytic Notes

There are over 800 laboratory tests performed on NHANES participants. However, not all participants provided biospecimens or enough volume for all the tests to be performed. The specimen availability can also vary by age or other population characteristics. Analysts should evaluate the extent of missing data in the dataset related to the outcome of interest as well as any predictor variables used in the analyses to determine whether additional re-weighting for item non-response is necessary.

Please refer to the NHANES Analytic Guidelines and the on-line NHANES Tutorial for further details on the use of sample weights and other analytic issues.

Phlebotomy Weights

For the August 2021-August 2023 cycle, analysis of nonresponse patterns for the phlebotomy component in the MEC examination revealed differences by age group and race/ethnicity, among other characteristics. For example, approximately 67% of children aged 1-17 years who were examined in the MEC provided a blood specimen through phlebotomy, while 95% of examined adults aged 18 and older provided a blood specimen. Therefore, an additional phlebotomy weight, WTPH2YR, has been included in this data release to address possible nonresponse bias. Participants who are eligible but did not provide a blood specimen have their phlebotomy weight assigned a value of "0" in their records. The phlebotomy weight should be used for analyses that use variables derived from blood analytes, and is included in all relevant data files.

Demographic and Other Related Variables

The analysis of NHANES laboratory data must be conducted using the appropriate survey design and demographic variables. The NHANES August 2021–August 2023 Demographics File contains demographic data, health indicators, and other related information collected during household interviews as well as the sample design variables. The recommended procedure for variance estimation requires use of stratum and PSU variables (SDMVSTRA and SDMVPSU, respectively) in the demographic data file.

The Fasting Questionnaire File includes auxiliary information, such as fasting status, length of fast, and the time of venipuncture.

This laboratory data file can be linked to the other NHANES data files using the unique survey participant identifier (i.e., SEQN).

Detection Limits

The detection limits were constant for all of the analytes in the data set. Two variables are provided for each of these analytes. The variable name ending in "LC" (ex., LBDBCDLC) indicates whether the result was below the limit of detection: the value "0" means that the result was at or above the limit of detection, "1" indicates that the result was below the limit of detection. The other variable prefixed URX (ex., LBXBCD) provides the analytic result for the analyte. For analytes with analytic results below the lower limit of detection (ex. LBDBCDLC=1), an imputed fill value was placed in the analyte results field. This value is the lower limit of detection divided by the square root of 2 (LLOD/sqrt[2]).
The lower limit of detection (LLOD, in µg/L) for cadmium, manganese, total mercury and selenium, and (LLOD, in ug/dL) for lead:

Variable Name	Analyte Description	LLOD
LBXBCD	Cadmium, blood	0.065
LBXBPB	Lead, blood	0.049
LBXMN	Manganese, blood	0.52
LBXTHG	Mercury, total, blood	0.17
LBXBSE	Selenium, blood	9.90

References

- Caudill, S.P., Schleicher, R.L., Pirkle, J.L. Multi-rule quality control for the age-related eye disease study. Statist. Med. (2008) 27(20):4094-40106.
- Lutz, T.M., P.M.V. Nirel, and B. Schmidt, Whole-blood analysis by ICP-MS. Applications of Plasma Source Mass Spectrometry, ed. G. Holland and A.N. Eaton. 1991, Cambridge: Royal Soc Chemistry. 96-100.
- Tanner, S.D., Baranov, Vladimir I, Theory, Design, and Operation of a Dynamic Reaction Cell for ICP-MS. Atomic Spectroscopy, 1999. 20(2): p. 45-52.
- Tanner, S.D., V.I. Baranov, and D.R. Bandura, Reaction cells and collision cells for ICP-MS: a tutorial review. Spectrochimica Acta Part B-Atomic Spectroscopy, 2002. 57(9): p. 1361-1452.
- Westgard J.O., Barry P.L., Hunt M.R., Groth T. A multi-rule Shewhart chart for quality control in clinical chemistry. Clin Chem. 1981 Mar; 27(3):493-501.

Codebook and Frequencies

SEQN - Respondent sequence number

Variable Name:	SEQN
SAS Label:	Respondent sequence number
English Text:	Respondent sequence number
Target:	Both males and females 1 YEARS - 150 YEARS

WTPH2YR - Phlebotomy 2 Year Weight

Variable Name: WTPH2YR

SAS Label: Phlebotomy 2 Year Weight

English Text: Phlebotomy 2 Year Weight

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
4391.8220579 to 253478.77765	Range of Values	7626	7626	
0	No blood sample provided	1101	8727	
.	Missing	0	8727	

LBXBPB - Blood lead (ug/dL)

Variable Name: LBXBPB

SAS Label: Blood lead (ug/dL)

English Text: Blood lead (ug/dL)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0.085 to 48.07	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBPBSI - Blood lead (umol/L)

Variable Name: LBDBPBSI

SAS Label: Blood lead (umol/L)

English Text: Blood lead (umol/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0.004 to 2.322	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBPBLC - Blood lead comment code

Variable Name: LBDBPBLC

SAS Label: Blood lead comment code

English Text: Blood lead comment code

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0	At or above the detection limit	7586	7586	
1	Below lower detection limit	0	7586	
.	Missing	1141	8727	

LBXBCD - Blood cadmium (ug/L)

Variable Name: LBXBCD

SAS Label: Blood cadmium (ug/L)

English Text: Blood cadmium (ug/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0.046 to 8.379	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBCDSI - Blood cadmium (nmol/L)

Variable Name: LBDBCDSI

SAS Label: Blood cadmium (nmol/L)

English Text: Blood cadmium (nmol/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0.409 to 74.548	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBCDLC - Blood cadmium comment code

Variable Name: LBDBCDLC

SAS Label: Blood cadmium comment code

English Text: Blood cadmium comment code

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0	At or above the detection limit	7257	7257	
1	Below lower detection limit	329	7586	
.	Missing	1141	8727	

LBXTHG - Blood mercury, total (ug/L)

Variable Name: LBXTHG

SAS Label: Blood mercury, total (ug/L)

English Text: Blood mercury, total (ug/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0.12 to 42.49	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDTHGSI - Blood mercury, total (nmol/L)

Variable Name: LBDTHGSI

SAS Label: Blood mercury, total (nmol/L)

English Text: Blood mercury, total (nmol/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0.6 to 212.03	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDTHGLC - Blood mercury, total comment code

Variable Name: LBDTHGLC

SAS Label: Blood mercury, total comment code

English Text: Blood mercury, total comment code

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0	At or above the detection limit	5610	5610	
1	Below lower detection limit	1976	7586	
.	Missing	1141	8727	

LBXBSE - Blood selenium (ug/L)

Variable Name: LBXBSE

SAS Label: Blood selenium (ug/L)

English Text: Blood selenium(ug/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
86 to 867.7	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBSESI - Blood selenium (umol/L)

Variable Name: LBDBSESI

SAS Label: Blood selenium (umol/L)

English Text: Blood selenium (umol/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
1.09 to 11.02	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBSELC - Blood selenium comment code

Variable Name: LBDBSELC

SAS Label: Blood selenium comment code

English Text: Blood selenium comment code

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0	At or above the detection limit	7586	7586	
1	Below lower detection limit	0	7586	
.	Missing	1141	8727	

LBXBMN - Blood manganese (ug/L)

Variable Name: LBXBMN

SAS Label: Blood manganese (ug/L)

English Text: Blood manganese (ug/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
2.48 to 63.17	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBMNSI - Blood manganese (nmol/L)

Variable Name: LBDBMNSI

SAS Label: Blood manganese (nmol/L)

English Text: Blood manganese (nmol/L)

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
45.14 to 1149.82	Range of Values	7586	7586	
.	Missing	1141	8727	

LBDBMNLC - Blood manganese comment code

Variable Name: LBDBMNLC

SAS Label: Blood manganese comment code

English Text: Blood manganese comment code

Target: Both males and females 1 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
0	At or above the detection limit	7586	7586	
1	Below lower detection limit	0	7586	
.	Missing	1141	8727	