LEAD PAINT INGESTION STUDY

FINAL REPORT
25 February 1974

Contract No. 62-W-62GC&NPC
MRI Project No. 3729-B

For

National Paint and Coatings Association
1500 Rhode Island Avenue, N.W.
Washington, D. C. 20005

PREFACE

This report was prepared at Midwest Research Institute, 425 Volker Boulevard, Kansas City, Missouri 64110 under Contract No. 62-W-62GC & NPC, MRI Project No. 3729-B, "Lead Paint Ingestion Study." The Research was sponsored by the National Paint and Coatings Association, 1500 Rhode Island Avenue, N.W., Washington, D. C. 20005. Royal A. Brown, Technical Director, National Paint and Coatings Association was the project monitor.

The research was conducted in the Biological Sciences Division, under the direction of Dr. W. B. House from 1 December 1972 through 31 July 1973. Dr. Thomas R. Castles, Principal Pharmacologist, was the principal investigator, assisted by Dr. Jaime Sanyer, Associate Pathologist, and Mrs. Jane Hoch, Biology Research Assistant. Dr. James L. Spigarelli, Senior Chemist supervised the lead analysis with the assistance of Mrs. Hope M. Miller, Assistant Chemist.

Members of the National Paint and Coatings Association Industrial Metals Task Force prepared the paint chips and consulted with Drs. Castle, Sanyer, Spigarelli and House during the course of the study. The personnel of the NPCA Industrial Metals Task Force is as follows:

Richard A. Moore	-	The Sherwin Williams Company - Chairman
Royal A. Brown	-	The National Paint & Coatings Association
John P. Frawley	-	Hercules, Inc.
Charles M. Jackson	-	Celanese Coatings Co.
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Sidney Lauren	-	Coatings Research Group, Inc.
William W. Ringle	-	Pratt and Lambert, Inc.
Edwin E. Swain	-	E. I. duPont de Nemours & Co., Inc.
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Approved for:
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25 February, 1974

TABLE OF CONTENTS

I. INTRODUCTION

Few persons will disagree that the ingestion of old lead-based paint presents a potential health hazard to young children. As a result of reports by Kehoe,[1] Chisholm,[2] and King,[3] medical researchers, paint manufacturers and legislators have recognized the seriousness of this problem and are acting to establish safe concentrations of lead in paint. To do this, they have voluminous reports on clinical observations and animal research from which to draw. Unfortunately, most of this information is based upon the old white lead paints or soluble lead salts, which are not representative of the paint formulations on today's market. Some studies have been reported[4,5] which indicate that lead compounds are not as readily leached from modern paint films.

Before safe concentrations of lead in paint can be intelligently established, we must evaluate the toxicity of the lead as it exists currently in modern paints. It was the purpose of this study to evaluate the toxicity in rats produced by different concentrations of modern paints containing lead octoate and lead chromate at varying concentrations compared to an old paint formulation containing white lead. The results are presented in the following pages.

II. METHODS

A. Preparation of Paint Films Containing Different Concentrations of Lead

Paint films without added lead and with added lead compounds in the form of lead octoate, lead chromate, or lead carbonate were supplied by members of the National Paint and Coatings Association. Paints which contained lead octoate, and lead chromate (medium yellow) were prepared using a flat alkyd paing formula based upon a Federal Specification TT-R-266D Type I Class B alkyd resin. A white lead in oil paint was prepared from a formula typical of this type paint as it was used in the 1920's. This contained a high percentage of lead carbonate. The flat alkyd paint without added lead was used for control. The percent of lead in each sample was calculated on the basis of the nonvolatile material. Dispersion was accomplished with a Cowles Dissolver and the pigment volume concentration was held at one level. The paints were placed in pans and allowed to air dry. This was followed by forced air drying at 120°F to volatilize any remaining solvent. Paint films were ground and sieved, and chips ranging from 0.5 to 1.0 mm in size were used for this study. This chip size was selected on the basis of a preliminary rat feeding study which established that rats would selectively eat around larger sized chips but would eat chips in the selected size range.

The concentrations of lead in the different paint films were determined independently by DeSoto Incorporated, the Sherwin-Williams Company and Midwest Research Institute, using Atomic Absorption Spectrophotometry.

Twenty male and 20 female rats were assigned to the control diet, and 10 males and 10 female rats were assigned to each of the remaining diets. Each diet was fed in a 9-oz wide-mouth glass jar which was secured to the cage. Tap water was available ad libitum during the entire experiment.

Feed consumption was measured twice each week and calculated on a daily basis. The animals were weighed once a week. All rats were observed twice or more each week for toxic signs.

After 4, 8 and 13 weeks, a selected number of male and female rats from each group were placed in metabolism cages for the collection of 24-hr urine samples. A portion of the collected urine was used for urinalysis and the remainder frozen for assay of delta-aminolevulinic acid and coproporphyrin. After urine collection each rat was anesthesized with ether, exsanguinated via the abdominal aorta and bone marrow smears were prepared. Blood samples were heparizined, cooled and used immediately for hematology and enzyme assays. Aliquots of the remaining blood were taken for protoporphyrin and lead assays. After urine and blood samples were obtained, each rat was necropsied and tissue taken for lead analysis or microscopic examination.

D. Analysis

1. Lead analyses of paint chips and diets containing paint chips:

a. Paint film: Ten-milligram samples of paint chips containing no lead or 0.08% lead octoate were charred with 3 ml of concentrated nitric acid and dry-ashed at 500° C for 2 hr. The ash was dissolved in 1 ml of aqua regia, diluted to 5 ml with distilled water and this final dilution measured for lead content by atomic absorption.

All other paint chips (10 mg samples) were digested in 15 ml of a mixture of concentrated nitric acid and 37% perchloric acid (2:1, V/V), evaporated and the remaining perchloric acid solution diluted to 25 ml with distilled water. This final dilution was used for atomic absorption spectrophotometry.

b. Diets: One-gram samples of feed were digested in a mixture of concentrated nitric acid and 37% perchloric acid (2:1, V/V) and their final dilutions adjusted to make their lead concentrations within the detection limits of the atomic absorption technique.

A sample of old lead-based paint collected from walls of old dwellings was obtained from the U. S. Department of Commerce, National Bureau of Standards, Washington, D.C. This paint was intended as an analytical standard and had been pulverized and sieved through 325 mesh screen (0.06-0.08 mm size) and contained 11.92% lead by weight as carbonate. This sample will be referred to as "NBS lead paint" in this report.

B. Preparation of Diets

Diets were prepared by mixing paint chips with Purina Rat Chow mash in the concentration of 0.1% (weight/weight). This was accomplished by first preparing a 10% concentrate (paint film/feed, w/w) in a high-speed twin shell mixer. This concentrate was then added to the appropriate amount of Purina Rat Chow mash to give a final concentration of 0.1% (paint film/feed, w/w) and mixed for 10 minutes in a bulk mixer.

Each diet was prepared three times during the experiment and samples of each of these preparations were assayed for lead content.

C. Experimental Procedure

Two hundred weanling (40-60 gm) Charles River rats (100 males and 100 female rats) were used for this study. Upon arrival rats were housed individually in air conditioned quarters in polycarbonate cages containing hardwood bedding and filter tops. After 5-7 days of equilibration, all rats were assigned one of the following diets.

1. Rat chow plus paint chips without added lead (control)
2. Rat chow plus paint chips containing 0.08% lead as lead octoate
3. Rat chow plus paint chips containing 0.53% lead as lead octoate
4. Rat chow plus paint chips containing 2.05% lead as lead octoate
5. Rat chow plus paint chips containing 0.42% lead as lead chromate
6. Rat chow plus paint chips containing 1.95% lead as lead chromate
7. Rat chow plus paint chips containing 12.43% lead as lead chromate
8. Rat chow plus paint chips containing 66.05% lead as lead carbonate
9. Rat chow plus NBS lead paint containing 11.92% lead as carbonate

(5) Urinary coproporphyrin: Urinary coproporphyrins were determined by the method of Schlenker and Kitchell.[12] These analyses were performed in subdued light.

c. Urinalysis:

(1) Urinary protein (albumin): Urinary protein was measured with "Uristix" reagents strips (Ames Company, Elkhart, Indiana).

(2) Microscopic examination of urine: Urine samples were centrifuged, the residues resuspended, and examined microscopically for the presence of erythrocytes and leukocytes under high power field and for casts under low power field.

d. Tissue lead:

(1) Blood: One milliliter of blood was mixed with 1 ml of a mixture of 5% trichloroacetic acid: 37% perchloric acid (3:1 v/v). The sample was centrifuged and the supernatant filtered through an AAWP 0.8 μ Millipore filter. The supernate was analyzed for lead with an atomic absorption spectrophotometer using standards prepared in control rat blood.

(2) Other tissues: Bone, liver, kidney, and brain were digested in concentrated nitric acid, evaporated to dryness and reconstituted to the lowest possible volume with 20% nitric acid. These solutions were analyzed for lead by atomic absorption spectrophotometry.

(3) Atomic absorption analysis: Lead concentrations were measured using a Varian-Techtron AA-5 atomic absorption spectrophotometer. Sample solutions were aspirated into an air-acetylene flame and the absorbance was measured at 283.3 nm. Background interference was determined with the use of a hydrogen continuum lamp at 283.3 nm and subtracted from the absorbance obtained at 283.3 nm with the Pb hollow cathode lamp.

E. Pathology

1. Gross pathology: At necropsy, rats were examined for gross abnormalities, their livers, kidneys, spleens, hearts, gonads, thyroids, brains, and adrenals weighed, and the relative organ weights calculated. After weighing, a portion of the liver, kidney and brain were taken for microscopic examination and the rest of each organ was measured for lead content. A femur was removed to be used for the measurement of lead in bone.

2. Microscopic pathology: Bone marrow smears were prepared for myeloid/erythroid cell count. The following tissues were fixed in buffered neutral 10% formalin: brain, liver, spleen, stomach, small intestine (duodenum, jejunum, ileum),

2. Analyses performed upon each rat:

a. Hematology:

(1) Hematocrit: Hematocrit was determined in capillary tubes using a microcapillary centrifuge (International Equipment Company, Bodel MB).

(2) Hemoglobin: Hemoglobin was measured as cyanomethemoglobin.[13]

(3) Erythrocyte and leukocyte counts: Total erythrocyte and leukocyte were counted using a Coulter Electronic Particle Counter with 100-μ aperature.[16]

(4) Reticulocytes: Reticulocytes were counted by the methylene blue method using the Miller disc.[6]

(5) Differential leukocyte counts: Wright's stain was used to stain the leukocytes for examination.

(6) Erythrocyte osmotic fragility: Osmotic fragility of erythrocytes was quantitatively determined by subjecting heparinized whole blood to sodium chloride solutions of different osmolarities.[7] The concentration of sodium chloride which hemolyzed 50% of the erythrocytes was obtained from a plot of percent hemolysis versus sodium chloride concentration.

b. Body fluid and tissue chemistry:

(1) Plasma protein electrophoretic patterns: Total plasma protein was determined using the Hycel Biuret Reagent (Hycel, Inc., Houston, Texas). The quantity of each plasma protein was determined electrophoretically on cellulose acetate and expressed as a percentage of the total plasma protein.

(2) Erythrocyte-δ-aminolevulinic acid dehydrase (ALAD): δ-Aminolevulinic acid dehydrase activity was determined by the method of Lichtman and Feldman.[8] This procedure was started 30 min. after each blood sample was taken.

(3) Erythrocyte protoporphyrin: Protoporphyrin in erythrocytes was measured by the method of Heller, et al.[9] This analysis was performed the day after blood was withdrawn.

(4) Urinary δ-aminolevulinic acid (ALA): Urinary δ-aminolevulinic acid was measured according to the Davis and Andelman[10] modification of Mauzerall's and Granick's Method.[11] These analyses were performed in subdued light.

TABLE 1

CONCENTRATION OF LEAD IN PAINT FILM

Paint Film	Theoretical Lead Concentration (%)	Measured Lead Concentration		
		Paint Companies (%)	MRI (%)	Average[b] (%)
Control Paint	0	0.01	< 0.02	0.01
Lead octoate	0.06	0.08	0.07	0.08
Lead octoate	0.50	0.50	0.56	0.53
Lead octoate	2.00	1.90	2.20	2.05
Lead chromate	0.50	0.42	0.41	0.42
Lead chromate	2.00	1.80	2.10	1.95
Lead chromate	15.00	12.57	12.30	12.43
Lead carbonate	64.12	63.20	68.90	66.05
NBS lead paint	-	11.87[a]	11.98	11.92[c]

a/ Measured by U.S. Department of Commerce, National Bureau of Standards, Washington, D.C.

b/ Average of paint companies and MRI values.

c/ Average of Bureau of Standards and MRI values.

colon, pancreas, kidneys, urinary bladder, adrenals, thymus, gonad, thyroid (with parathyroid attached), mesenteric salivary gland, lymph nodes, heart, lungs, diaphragm, skeletal muscle, and prostate or uterus.

Tissues from all 13 week rats fed the control, 2.05% lead octoate, 12.43% lead chromate, 66.05% lead carbonate, and the 11.92% NBS lead paint diets were embedded in paraffin, section to a thickness of 6 μ, stained with hematoxylin and eosin and examined for histopathology.

F. Statistical Analyses

Control and treatment values were compared statistically using Dunnett's multiple-comparison test with $P<0.05$ as the criteria of significance.

III. RESULTS

A. Concentrations of Lead in Paint Chips

The concentrations of lead in the paint chips supplied by the Members of the National Paint and Coatings Association were analyzed for lead content by DeSoto Incorporated, the Sherwin-Williams Company, and Midwest Research Institute (MRI). The results of these analyses are shown in Table 1. The control paint which did not contain lead octoate or chromate was found to contain approximately 0.01% lead. There was a reasonable agreement between the different analyses, so an average ppm of lead was computed and used for the actual lead concentration of each paint film. Lead concentrations of the lead paint obtained from the National Bureau of Standards were averaged in a similar manner.

B. Lead Analyses of Diets Containing Different Paint Films

Table 2 shows the lead content of each diet. Purina Rat Chow mash was found to contain approximately 4 μg/gm of lead (assuming 0.1 μg/gm of lead was contributed by the control paint). The μg of lead/gm of feed which was attributable to each added paint film was reasonably close to its respective theoretical value. The average total μg of lead/gm of feed for each diet was used for the calculation of weekly and total lead consumption for each rat.

C. Preliminary Feeding Studies

Before beginning this study, a pilot experiment was performed to see if the rats were consuming the lead paint chips along with their feed. Three rats each were placed on the control diet and the 66.05% lead carbonate diet. After 48 hr, their feces were collected and the lead content measured. Feces from rats on the control diet contained 11.5 μg of lead/gm feces while feces from rats fed the 66.05% lead carbonate diet contained 3,683 μg of lead/gm feces. Thus, rats did consume the paint film along with their feed.

D. Gross Observations, Feed Consumptions and Body Weights

During the entire study only two rats had remarkable changes. One female rat on 2.05% lead octoate developed an abcess on her left shoulder during the ninth treatment week and one female on 66.05% lead carbonate developed abcessed hind feet in the 10th week and chewed her toes off.

The feed consumptions of male and female rats are shown in Figures 1 and 2, respectively. Each bar represents the mean ± standard error of six to twenty rats. Except for the rats fed the diet containing 11.92% lead as NBS lead paint, all groups consumed feed at the same rate as the control group throughout the entire experiment. The reason the 11.92% NBS lead paint group ate significantly less initially, was that they were started a month after the other rats and were initially smaller. Since this group was consuming feed at the same rate as the control group by 4 weeks, we consider their initial food consumption normal also (for their size).

The body weight gains for each group of rats are shown in Figures 3 and 4. Each bar represents the mean ± standard error of six to twenty rats. As mentioned above, the rats on the 11.92% NBS lead paint diet were small initially but became similar to controls by either the 4th (females) or 8th week (males). Throughout the entire period the male rats in the other treatment groups gained weight at a normal rate. The female rats did show a change in body weights during the first 8 weeks of feeding which appears related to the concentration of lead octoate. After 4 weeks of feeding, rats in the 2.05% lead octoate group weighed significantly less than control. The pattern was the same at 8 weeks. After 12 weeks their average body weights still exhibited the same pattern, but the 2.05% lead octoate group was not significantly different from control. This was due to fewer animals and a slight increase in variability.

TABLE 2

LEAD ANALYSES OF DIETS CONTAINING DIFFERENT PAINT FILMS

Diet	Theoretical[a] (µg/gm)	Measured Total[b] (µg/gm)	Measured Paint Lead[c] (µg/gm)
Control paint plus rat chow	0.1	4.1 (6)	-
Lead octoate (0.08%) plus rat chow	0.8	5.2 (6)	1.1 (6)
Lead octoate (0.53%) plus rat chow	5.3	12.0 (6)	7.9 (6)
Lead octoate (2.05%) plus rat chow	20.5	27.2 (6)	23.1 (6)
Lead chromate (0.42%) plus rat chow	4.2	11.0 (6)	6.9 (6)
Lead chromate (1.95%) plus rat chow	19.5	23.5 (6)	19.4 (6)
Lead chromate (12.43%) plus rat chow	124.3	140.2 (6)	136.1 (6)
Lead carbonate (66.05%) plus rat chow	660.5	516.0 (5)	511.9 (5)
NBS lead paint (11.92%) plus rat chow	119.2	124.0 (3)	119.9 (3)

a/ Theoretical concentration of lead in feed contributed by indicated paint film.
b/ Mean µg of lead/gm feed for number of samples shown in parenthesis.
c/ Mean µg of lead from paint films/gm feed for number of samples shown in parenthesis.

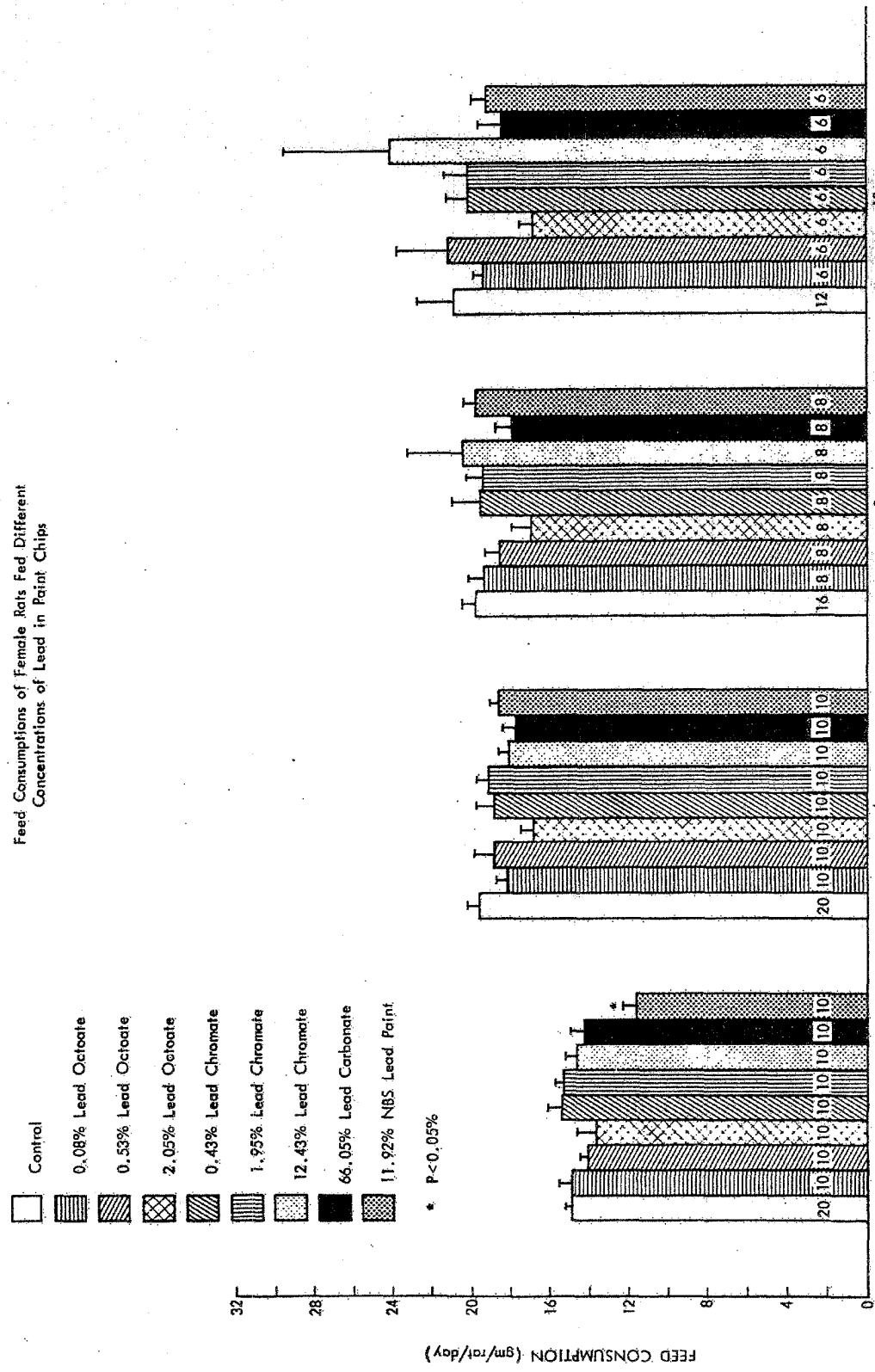

Figure 2

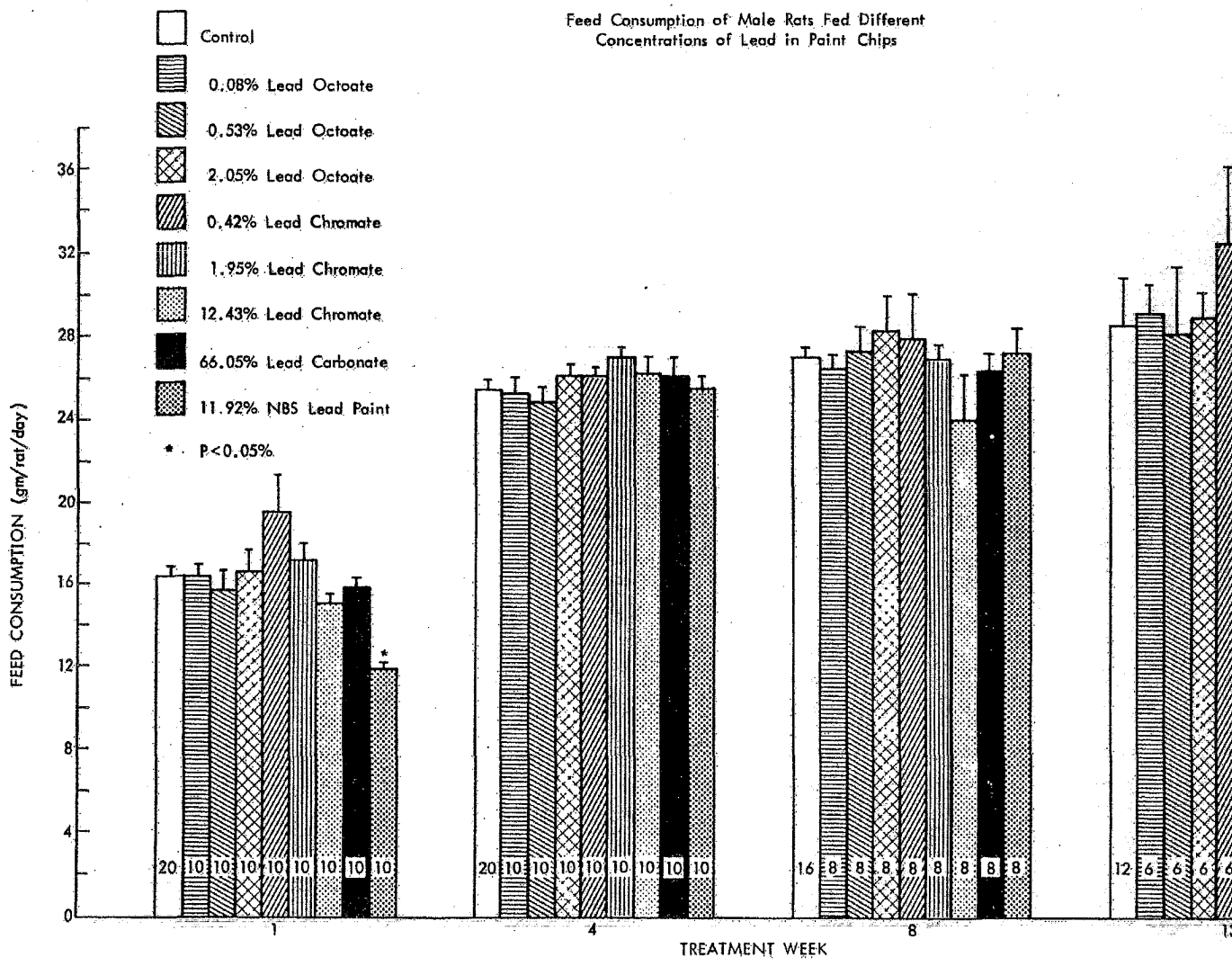

Figure 1

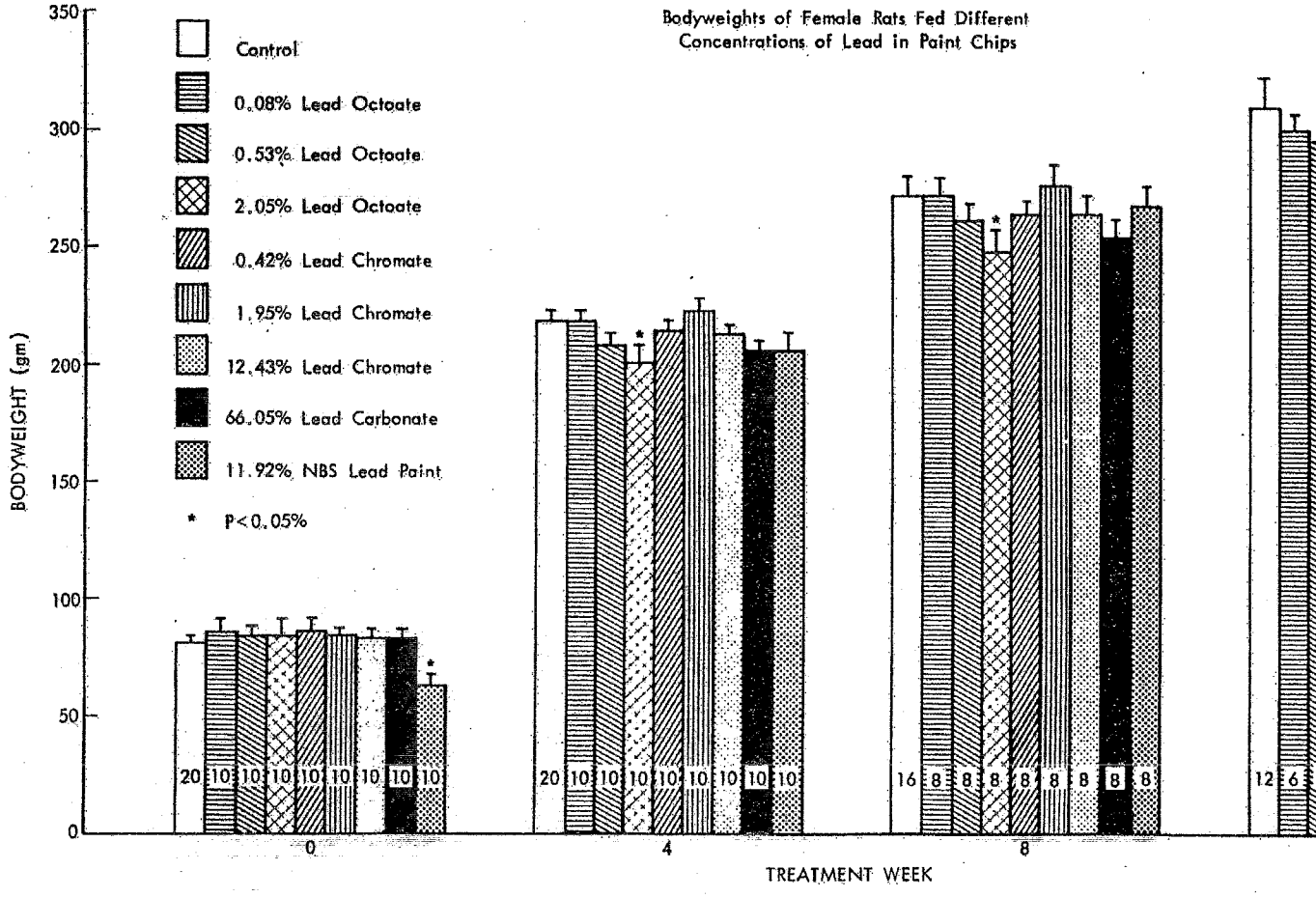
Bodyweights of Female Rats Fed Different Concentrations of Lead in Paint Chips
Control
0.08% Lead Octoate
0.53% Lead Octoate
2.05% Lead Octoate
0.42% Lead Chromate
1.95% Lead Chromate
12.43% Lead Chromate
66.05% Lead Carbonate
11.92% NBS Lead Paint
* P<0.05%
BODYWEIGHT (gm)
350
300
250
200
150
100
50
0
20 10 10 10 10 10 10 10 10
20 10 10 10 10 10 10 10 10
16 8 8 8 8 8 8 8 8
12 6
0
4
8
TREATMENT WEEK

Figure 4

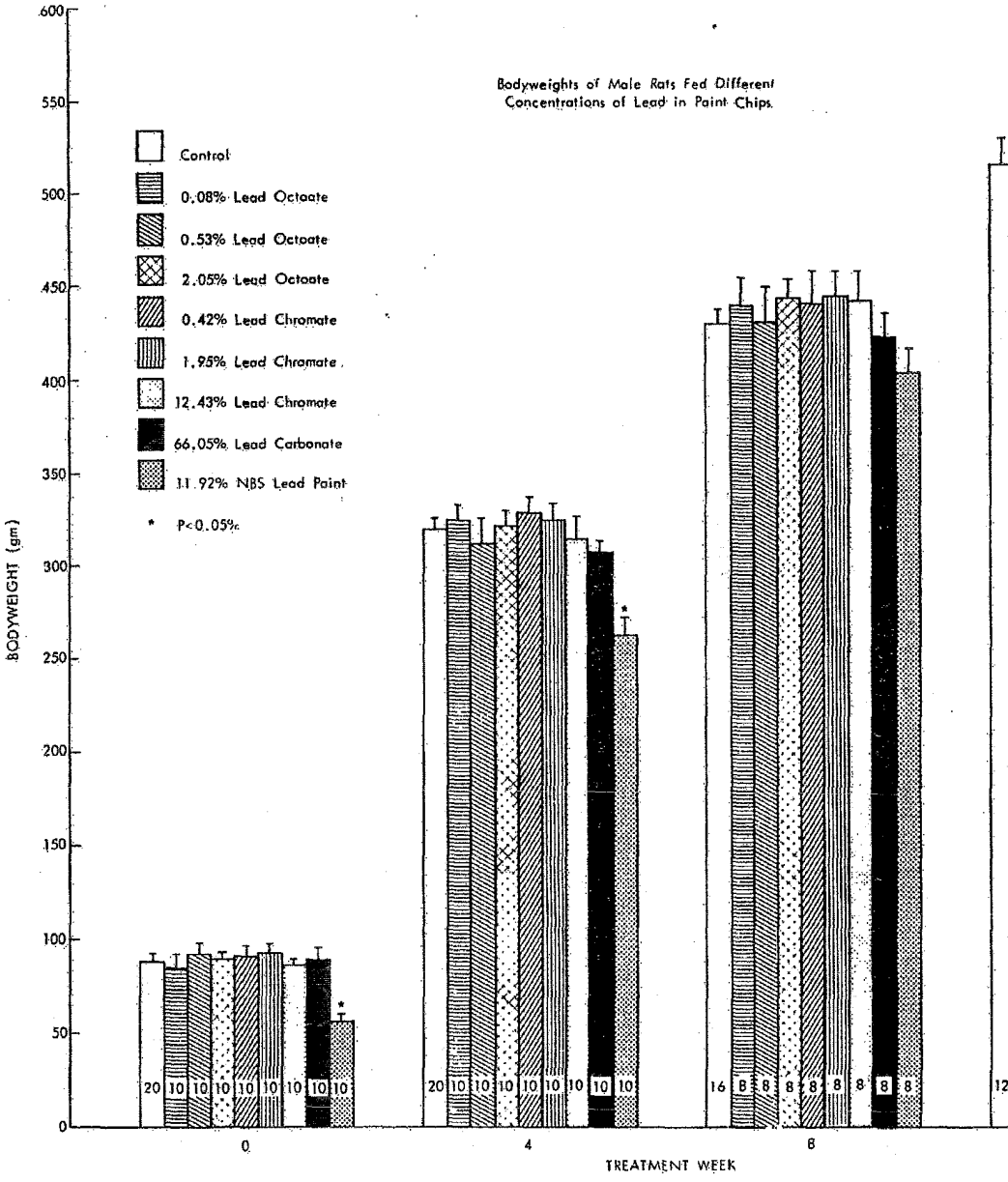
Bodyweights of Male Rats Fed Different Concentrations of Lead in Paint Chips
Control
0.08% Lead Octoate
0.53% Lead Octoate
2.05% Lead Octoate
0.42% Lead Chromate
1.95% Lead Chromate
12.43% Lead Chromate
66.05% Lead Carbonate
11.92% NBS Lead Paint
* P<0.05%
BODYWEIGHT (gm)
600
550
500
450
400
350
300
250
200
150
100
50
0
20 10 10 10 10 10 10 10 10
20 10 10 10 10 10 10 10 10
16 8 8 8 8 8 8 8 8
12
0
4
8
TREATMENT WEEK

Figure 3

TABLE 3

WEEKLY AND TOTAL LEAD CONSUMPTION BY MALE RATS FED PAINT CHIPS

	Treatment Week											
	1 (µg)	2 (µg)	3 (µg)	4 (µg)	5 (µg)	6 (µg)	7 (µg)	8 (µg)	9 (µg)	10 (µg)	11 (µg)	12 (µg)
Control	470.7[a/] (20)	597.0 (20)	638.1 (20)	731.8 (20)	749.1 (16)	769.2 (16)	806.5 (16)	774.9 (16)	751.9 (12)	786.4 (12)	838.0 (12)	829.4 (12)
Lead octoate 0.08%	597.0 (10)	775.3 (10)	888.2 (10)	920.9 (10)	957.3 (8)	968.2 (8)	979.2 (8)	964.6 (8)	997.4 (6)	1,011.9 (6)	1,044.7 (6)	1,019.2 (6)
0.53%	1,310.4 (10)	1,780.8 (10)	1,806.0 (10)	2,091.6 (10)	2,242.8 (8)	2,158.8 (8)	2,444.4 (8)	2,301.6 (8)	2,268.0 (6)	2,284.8 (6)	2,209.2 (6)	2,352.0 (6)
2.05%	3,179.7 (10)	4,017.4 (10)	4,569.6 (10)	4,988.5 (10)	5,140.8 (8)	5,064.6 (8)	5,064.6 (8)	5,407.4 (8)	5,388.3 (6)	5,369.3 (6)	5,274.1 (6)	5,464.5 (6)
Lead chromate 0.42%	1,501.5 (10)	1,717.1 (10)	1,886.5 (10)	2,017.4 (10)	2,163.7 (8)	2,148.3 (8)	2,140.6 (8)	2,156.0 (8)	2,132.9 (6)	2,363.9 (6)	2,233.0 (6)	2,310.0 (6)
1.95%	2,829.4 (10)	3,767.1 (10)	3,931.6 (10)	4,458.0 (10)	4,211.2 (8)	4,507.3 (8)	4,688.3 (8)	4,441.5 (8)	5,560.1 (6)	5,296.9 (6)	5,971.4 (6)	5,724.6 (6)
12.43%	14,721.0 (10)	20,413.1 (10)	22,964.8 (10)	25,810.8 (10)	27,282.9 (8)	28,068.0 (8)	27,969.9 (8)	23,553.6 (8)	22,081.5 (6)	24,044.3 (6)	30,227.1 (6)	28,951.3 (6)
Lead carbonate 66.05%	57,430.8 (10)	75,129.6 (10)	85,243.2 (10)	94,634.4 (10)	98,607.6 (8)	97,885.2 (8)	101,497.2 (8)	95,156.8 (8)	102,219.6 (6)	102,942.0 (6)	104,025.6 (6)	102,942.0 (6)
NBS Lead paint 11.92%	10,242.4 (10)	14,148.4 (10)	19,356.4 (10)	22,134.0 (10)	22,654.8 (8)	23,436.0 (8)	24,738.0 (8)	23,696.4 (8)	22,828.4 (6)	24,998.4 (6)	24,564.4 (6)	26,474.0 (6)

a/ Average µg of lead consumed/rat/week for the number of rats shown in parenthesis.
b/ Average total mg of lead consumed/rat for the rats surviving 13 weeks.

E. Weekly and Total Lead Consumption

The weekly and total lead consumption during the experiment were calculated on the basis of the total lead/diet and amount of each diet eaten by each rat. These calculations are shown in Tables 3 and 4. During the 13th week period, the control group consumed approximately 105 μg (males) or 79 μg (females) of lead/day, while rats eating 2.05% lead octoate, 12.43% lead chromate, 66.05% lead carbonate, or 11.92% NBS lead paint consumed an average of 787 μg (males) or 708 μg (females); 3,591 μg (males) or 2,689 μg (females); 13,436 μg (males) or 9,185 μg (females); and 3,184 μg (males) or 2,363 μg(females) of lead/day, respectively. Using the average body weights of rats surviving 13 days, the rats in the control, 2.05% lead octoate, 12.43% lead chromate, 66.05% lead carbonate and the 11.92% NBS lead paint groups consumed 288 μg (males) or 335 μg (females) of lead/kg/day; 2,133 μg (males) or 3,278 μg (females) of lead/kg/day; 9,785 μg (males) or 11,590 μg (females) of lead/kg/day; 37,014 μg (males) or 42,133 μg (females) of lead/kg/day; and 9,888 μg (males) or 10,364 μg (females) of lead/kg/day, respectively.

F. Hematology of Rats Fed Paint Chips Containing Different Concentrations of Lead

The results of the hematology of rats fed pain films containing different concentrations of lead are shown in Tables 5-13. No differences were observed in the erythrocyte count, reticulocyte count, hematocrit, leukocyte count, differential leukocyte count, and the erythrocyte osmotic fragility. At 13 weeks, the hematocrits of rats fed the NBS lead paint were significantly lower than control, while the hematocrits of the rats fed the other diets were normal.

G. Tissue and Fluid Chemistry of Rats Fed Paint Chips Containing Different Concentrations of Lead

Tables 14-22 show the tissue and fluid chemistry of rats fed paint chips containing different concentrations of lead. The serum proteins, erythrocyte protoporphyrin, urinary coproporphyrin, and urinary delta-aminolevulinic acid were not altered by any of the diets.

The activity of the erythrocyte enzyme, delta-aminolevulinic acid dehydrase (ALAD), in the control, lead octoate (0.08%, 0.53%, and 2.05%) and lead chromate (0.42%, 1.95% and 12.43%) groups did not differ throughout the experiment (Tables 23). ALAD activity was depressed in rats fed 66.05% lead carbonate and 11.92% NBS lead paint. At 4 weeks (Table 21, 22) there was a depression of 56% and 59% in these two groups, respectively. At 8 weeks the ALAD activity was depressed 44% in the 66.05% lead carbonate group, but the ALAD activity in the NBS lead paint group was not significantly different from control. At this time a sex difference was observed in both of these groups. The ALAD activity in the male rats remained depressed at the 4-week levels while the ALAD activities of the female rats returned to control levels. This sex difference may be linked to the fact that these female rats had matured and were probably beginning their menstrual cycles.

TABLE 5

HEMATOLOGY OF RATS FED PAINT CHIPS CONTAINING NO LEAD

Analyses	Treatment Week 4 (N=8)[a]	8 (N=8)	13 (N=24)
Erythrocytes (x 10^6/mm^3)	6.17 ± 0.14[b]	6.33 ± 0.19	6.42 ± 0.29
Reticulocytes, %	1.5 ± 0.7	0.8 ± 0.3	1.4 ± 0.1
Hematocrit, vol %	46.1 ± 0.8	44.6 ± 1.2	44.6 ± 0.3
Hemoglobin, gm %	14.0 ± 0.3	14.6 ± 0.3	16.0 ± 0.1
Leukocytes (x 10^3/mm^3)	5.0 ± 0.5	7.6 ± 1.3	8.0 ± 0.6
Neutrophils, %	11.8 ± 2.9	21.7 ± 5.6	13.1 ± 1.5
Lymphocytes, %	86.3 ± 3.3	75.4 ± 5.3	84.1 ± 1.6
Bands, %	0.3 ± 0.2	0	0.1 ± 0.1
Eosinophils, %	0.9 ± 0.4	1.3 ± 0.4	0.5 ± 0.2
Basophils, %	0	0	0
Monocytes, %	1.1 ± 0.6	1.6 ± 0.6	2.1 ± 0.4
Atypical, %	0	0	0
Nucleated RBC, %	0	0	0.1 ± 0.1
Erythrocyte osmotic fragility [NaCl][c]	0.381 ± 0.004	0.391 ± 0.008	0.400 ± 0.004

a/ Number of rats per period.
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 4

WEEKLY AND TOTAL LEAD CONSUMPTION BY FEMALE RATS FED PAINT CHIPS

	Treatment Week													
	1 (µg)	2 (µg)	3 (µg)	4 (µg)	5 (µg)	6 (µg)	7 (µg)	8 (µg)	9 (µg)	10 (µg)	11 (µg)	12 (µg)	13 (µg)	Total[b] (mg)
Control	427.6[a] (20)	502.3 (20)	533.8 (20)	559.7 (20)	608.4 (16)	591.2 (16)	565.4 (16)	568.3 (16)	576.9 (12)	582.6 (12)	579.7 (12)	545.3 (12)	597.0 (12)	7.2 (12)
Lead octoate 0.08%	542.4 (10)	655.2 (10)	644.3 (10)	658.8 (10)	702.5 (8)	695.2 (8)	691.6 (8)	706.2 (8)	684.3 (6)	717.1 (6)	753.5 (6)	684.3 (6)	702.5 (6)	8.8 (6)
0.53%	1,184.4 (10)	1,352.4 (10)	1,478.4 (10)	1,579.2 (10)	1,579.2 (8)	1,671.6 (8)	1,621.2 (8)	1,562.4 (8)	1,528.8 (6)	1,528.8 (6)	1,570.8 (6)	1,932.0 (6)	1,780.8 (6)	20.4 (6)
2.05%	3,179.7 (10)	4,017.4 (10)	4,569.6 (10)	4,988.5 (10)	5,140.8 (8)	5,064.6 (8)	5,064.6 (8)	5,407.4 (8)	5,388.3 (6)	5,369.3 (6)	5,274.1 (6)	5,464.5 (6)	5,521.6 (5)	64.4 (6)
Lead chromate 0.42%	1,185.8 (10)	1,316.7 (10)	1,401.4 (10)	1,447.6 (10)	1,486.1 (8)	1,586.2 (8)	1,578.5 (8)	1,509.2 (8)	1,540.0 (6)	1,540.0 (6)	1,439.9 (6)	1,601.6 (6)	1,540.0 (6)	19.2 (6)
1.95%	2,500.4 (10)	2,961.0 (10)	3,043.3 (10)	3,142.0 (10)	3,339.4 (8)	3,388.7 (8)	3,339.4 (8)	3,207.8 (8)	3,339.4 (6)	3,421.6 (6)	3,421.6 (6)	3,668.4 (6)	3,290.0 (6)	42.0 (6)
12.43%	14,328.4 (10)	17,174.5 (10)	16,978.2 (10)	17,763.3 (10)	21,002.0 (8)	19,922.4 (8)	19,628.0 (8)	20,118.7 (8)	18,646.6 (6)	18,450.3 (6)	18,842.9 (6)	17,959.6 (6)	23,848.0 (6)	244.7 (6)
Lead carbonate	51,290.4 (10)	59,959.2 (10)	61,404.0 (10)	63,932.4 (10)	68,628.0 (8)	66,099.6 (8)	67,905.6 (8)	64,654.8 (8)	66,822.0 (6)	63,932.4 (6)	65,738.4 (6)	69,350.4 (6)	66,099.6 (6)	835.8 (6)
NBS lead paint 11.92%	9,982.0 (10)	14,148.4 (10)	16,578.8 (10)	16,144.8 ((10)	- [c]	18,488.4 (8)	19,096.0 (8)	17,273.2 (8)	15,450.4 (6)	17,967.6 (6)	17,620.4 (6)	18,228.0 (6)	16,665.6 (6)	215.0[d] (6)

a/ Average µg of lead consumed/rat/week for the number of rats shown in parenthesis.
b/ Average total mg of lead consumed/rat for the rats surviving 13 weeks.
c/ Food consumption not measures.
d/ Total includes average Pb intake (17,316.6 µg/rat/week) for weeks 4 and 6 as an estimate for the week 5 intake.

TABLE 7

HEMATOLOGY OF RATS FED PAINT CHIPS
CONTAINING 0.53% LEAD AS LEAD OCTOATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	6.27 ± 0.2[b]	6.04 ± 0.31	5.6 ± 0.4
Reticulocytes, %	0.9 ± 0.7	0.9 ± 0.4	1.6 ± 0.2
Hematocrit, vol. %	42.3 ± 0.7	43.8 ± 0.5	43 ± 0.7
Hemoglobin, gm %	14.2 ± 0.2	14.9 ± 0.3	15.3 ± 0.3
Leukocytes (x 10^3/mm^3)	5.0 ± 1.4	7.5 ± 2.8	8.3 ± 1.0
Neutrophils, %	15.8 ± 3.8	19.3 ± 3.8	16.2 ± 1.9
Lymphocytes, %	83.0 ± 4.4	77.5 ± 3.8	81.4 ± 1.8
Bands, %	0	0	0.1 ± 0.1
Eosinophils, %	0.8 ± 0.3	1.0 ± 0.4	0.8 ± 0.3
Basophils, %	0	0	0
Monocytes, %	0.5 ± 0.5	2.3 ± 0.5	1.6 ± 0.3
Atypical, %	0	0	0
Nucleated RBC, %	0	0	0
Erythrocyte osmotic fragility [NaCl][c]	0.383 ± 0.006	0.388 ± 0.012	0.401 ± 0.006

a/ Number of rats per period.
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 6

HEMATOLOGY OF RATS FED PAINT CHIPS
CONTAINING 0.08% LEAD AS LEAD OCTOATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	6.14 ± 0.32[b]	6.33 ± 0.09	5.92 ± 0.39
Reticulocytes, %	0.9 ± 0.5	1.0 ± 0.5	1.4 ± 0.2
Hematocrit, vol. %	41.3 ± 0.9	46.0 ± 0.7	43.0 ± 0.5
Hemoglobin, gm %	14.1 ± 0.4	15.4 ± 0.2	14.7 ± 0.8
Leukocytes (x 10^3/mm^3)	5.1 ± 0.8	5.5 ± 0.7	7.7 ± 0.9
Neutrophils, %	24.5 ± 1.6	20.3 ± 4.7	16.3 ± 1.7
Lymphocytes, %	74.3 ± 1.8	76.3 ± 4.7	80.9 ± 1.8
Bands, %	0	0	0.3 ± 0.2
Eosinophils, %	0.8 ± 0.3	1.5 ± 0.6	0.7 ± 0.3
Basophils, %	0	0	0
Monocytes, %	0.5 ± 0.5	2.0 ± 0.8	1.9 ± 0.5
Atypical, %	0	0	0
Nucleated RBC, %	0	0	0
Erythrocyte osmotic fragility [NaCl][c]	0.381 ± 0.005	0.410 ± 0.007	0.395 ± 0.005

a/ Number of rats per period.
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 9

HEMATOLOGY OF RATS FED PAINT CHIPS
CONTAINING 0.42% LEAD AS LEAD CHROMATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	6.71 ± 0.16[b]	6.18 ± 0.16	6.6 ± 0.3
Reticulocytes, %	0.9 ± 0.8	0.8 ± 0.2	1.6 ± 0.2
Hematocrit, vol. %	43.3 ± 0.6	45.0 ± 1.1	43.6 ± 0.7
Hemoglobin, gm %	14.7 ± 0.4	15.1 ± 0.3	15.6 ± 0.3
Leukocytes (x 10^3/mm^3)	5.1 ± 0.6	5.1 ± 0.5	6.9 ± 0.7
Neutrophils, %	8.5 ± 1.7	19.0 ± 2.0	14.3 ± 2.1
Lymphocytes, %	90.3 ± 2.0	79.5 ± 1.3	83.4 ± 2.0
Bands, %	0	0	0
Eosinophils, %	0	0.8 ± 0.8	1.2 ± 0.4
Basophils, %	0	0	0
Monocytes, %	1.3 ± 0.8	0.8 ± 0.8	1.2 ± 0.4
Atypical, %	0	0	0
Nucleated RBC, %	0	0.3 ± 0.3	0
Erythrocyte osmotic fragility, [NaCl][c]	0.383 ± 0.003	0.395 ± 0.12	0.392 ± 0.007

a/ Number of rats per period, except where indicated otherwise
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 8

HEMATOLOGY OF RATS FED PAINT CHIPS
CONTAINING 2.05% LEAD AS LEAD OCTOATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	6.30 ± 0.2[b]	6.46 ± 0.08	6.72 ± 0.42
Reticulocytes, %	1.1 ± 0.6	0.7 ± 0.1	2.0 ± 0.6
Hematocrit, vol %	41.8 ± 0.5	45.0 ± 0.4	43.4 ± 0.8
Hemoglobin, gm %	14.4 ± 0.2	15.5 ± 0.2	15.6 ± 0.3
Leukocytes (x 10^3/mm^3)	5.1 ± 1.1	6.7 ± 1.7	8.1 ± 0.7
Neutrophils, %	13.5 ± 3.0	13.0 ± 2.1	14.1 ± 2.6
Lymphocytes, %	85.8 ± 3.2	85.0 ± 2.3	82.8 ± 2.8
Bands, %	0	0	0
Eosinophils, %	0.8 ± 0.5	0.3 ± 0.3	0.9 ± 0.3
Basophils, %	0	0	0
Monocytes, %	0	1.8 ± 0.9	2.2 ± 0.7
Atypical, %	0	0	0
Nucleated RBC, %	0	0	0
Erythrocyte osmotic fragility [NaCl][c]	0.381 ± 0.006	0.399 ± 0.008	0.393 ± 0.006

a/ Number of rats per period.
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 11

HEMATOLOGY OF RATS FED PAINT CHIPS
CONTAINING 12.43% LEAD AS LEAD CHROMATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	6.32 ± 0.14[b]	6.23 ± 0.18	6.61 ± 0.38
Reticulocytes, %	1.95 ± 1.28	0.9 ± 0.1	1.6 ± 0.2
Hematocrit, vol. %	41.3 ± 1.1	43.8 ± 0.5	44.1 ± 0.7
Hemoglobin, gm %	13.9 ± 0.4	15.2 ± 0.1	15.8 ± 0.2
Leukocytes (x 10^3/mm^3)	4.8 ± 0.5	5.3 ± 1.8	7.6 ± 0.6
Neutrophils, %	21.5 ± 6.3	15.0 ± 2.1	12.8 ± 1.6
Lymphocytes, %	78.0 ± 6.0	82.8 ± 2.0	84.8 ± 1.7
Bands, %	0	0	0.1 ± 0.1
Eosinophils, %	0.5 ± 0.5	1.0 ± 0	1.0 ± 0.4
Basophils, %	0	0	0
Monocytes, %	0	1.3 ± 0.3	1.3 ± 0.3
Atypical, %	0	0	0
Nucleated RBC, %	0	0.3 ± 0.3	0
Erythrocyte osmotic fragility [NaCl][c]	0.384 ± 0.007	0.385 ± 0.010	0.396 ± 0.006

a/ Number of rats per period.
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 10

HEMATOLOGY OF RATS FED PAINT CHIPS
CONTAINING 1.95% LEAD AS LEAD CHROMATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	6.17 ± 0.05[b]	6.21 ± 0.13	6.37 ± 0.52
Reticulocytes, %	0.8 ± 0.4	0.8 ± 0.3	1.2 ± 0.2
Hematocrit, vol. %	40.8 ± 0.6	44.3 ± 0.3	44.1 ± 0.7
Hemoglobin, gm %	13.9 ± 0.2	15.3 ± 0.3	16.2 ± 0.4
Leukocytes (x 10^3/mm^3)	4.9 ± 0.8	6.1 ± 1.2	8.2 ± 1.0
Neutrophils, %	10.0 ± 2.4	18.5 ± 6.6	11.4 ± 2.3
Lymphocytes, %	92.0 ± 1.8	80.5 ± 6.6	85.9 ± 2.2
Bands, %	0	0	0
Eosinophils, %	0.5 ± 0.3	0.3 ± 0.3	1.5 ± 0.5
Basophils, %	0	0	0
Monocytes, %	0	0.8 0.3	1.2 ± 0.3
Atypical, %	0	0	0
Nucleated RBC, %	0	0	0
Erythrocyte osmotic fragility, [NaCl][c]	0.383 ± 0.007	0.385 ± 0.007	0.404 ± 0.005

a/ Number of rats per period.
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 13

HEMATOLOGY OF RATS FED RBS LEAD PAINT CONTAINING 11.92% LEAD

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	5.72 ± 0.15[b]	4.49 ± 0.83	5.63 ± 0.34
Reticulocytes, %	2.5 ± 0.3	1.0 ± 0.4	1.3 ± 0.1
Hematocrit, vol. %	39.7 ± 0.8	42.8 ± 1.1	42.9 ± 0.4
Hemoglobin, gm %	13.6 ± [c]	14.7 ± 0.3	14.7 ± 0.1 [e]
Leukocytes (x 10^3/mm^3)	9.7 ± 1.4	6.7 ± 1.2	7.0 ± 0.5
Neutrophils, %	9.5 ± 2.1	7.0 ± 1.7	14.2 ± 2.1
Lymphocytes, %	90.2 ± 2.3	92.0 ± 2.1	83.6 ± 2.2
Bands, %	0.3 ± 0.3	0	0
Eosinophils, %	0	0	1.4 ± 0.4
Basophils, %	0	0	0
Monocytes, %	0	1.0 ± 0.7	0.8 ± 0.3
Atypical, %	0	0	0
Nucleated RBC, %	0	0	0.1 ± 0.1
Erythrocyte osmotic fragility [NaCl][d]	0.389 ± 0.006	0.412 ± 0.006	0.408 ± 0.005

a/ Number of rats per period, except where indicated otherwise.

b/ Mean ± standard error.

c/ Two rats.

d/ Concentration of NaCl that hemolyzes 50% of the erythrocytes.

e/ Significantly different from control ($P<0.05$) as hown by Dunnett's multiple-comparison test following an analysis of variance.

TABLE 12

HEMATOLOGY OF RATS FED PAINT CHIPS
CONTAINING 66.05% LEAD AS LEAD CARBONATE

Analyses	Treatment Week 4 (N=3)[a]	8 (N=4)	13 (N=12)
Erythrocytes (x 10^6/mm^3)	5.94 ± 0.56[b]	6.13 ± 0.06	6.60 ± 0.37
Reticulocytes, %	0.4 ± 0.2	1.1 ± 0.3	2.9 ± 1.3
Hematocrit, vol., %	41.3 ± 0.9	44.0 ± 1.5	44.7 ± 1.2
Hemoglobin, gm, %	13.9 ± 0.5	15.0 ± 0.2	15.6 ± 0.6
Leukocytes (x 10^3/mm^3)	4.3 ± 1.2	5.0 ± 0.9	7.7 ± 0.5
Neutrophils, %	14.3 ± 4.1	15.0 ± 4.1	15.2 ± 2.6
Lymphocytes, %	82.0 ± 5.6	84.0 ± 4.2	82.7 ± 2.7
Bands, %	0	0	0.2 ± 0.1
Eosinophils, %	0.7 ± 0.7	0.5 ± 0.5	0.9 ± 0.3
Basophils, %	0	0	0
Monocytes, %	3.0 ± 2.0	0.5 ± 0.3	1.0 ± 0.3
Atypical, %	0	0	0
Nucleated RBC, %	0	0	0.1 ± 0.1
Erythrocyte osmotic fragility [NaCl][c]	0.388 ± 0.009	0.394 ± 0.012	0.397 ± 0.005

a/ Number of rats per period.
b/ Mean ± standard error.
c/ Concentration of NaCl that hemolyzed 50% of the erythrocytes.

TABLE 15

TISSUE AND FLUID CHEMISTRY OF RATS FED PAINT CHIPS CONTAINING 0.08% LEAD AS LEAD OCTOATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	40 ± 1[b]	44 ± 3	48 ± 1
Alpha 1 globulin, %	26 ± 1	20 ± 2	20 ± 1
Alpha 2 globulin, %	5 ± 1	4 ± 1	5 ± 1
Beta globulin, %	21 ± 1	20 ± 1	22 ± 1
Gamma globulin, %	8 ± 1	12 ± 1	7 ± 1
Total protein, gm %	5.9 ± 0.1	6.3 ± 0.2	6.2 ± 0.1
Albumin/globulin ratio	0.66 ± 0.02	0.79 ± 0.08	0.93 ± 0.04
Erythrocytes			
ALAD, µmol. PBG/ Males:	24.8 ± 7.7[c]	14.9 ± 1.3[c]	12.0 ± 2.2[d]
100 ml RBC/hr Females:	19.5 ± 4.4[c]	18.7 ± 0.3[c]	16.1 ± 1.3[d]
Total:	22.2 ± 3.9	16.8 ± 1.2	14.0 ± 1.4
Protoporphyrin, µg/100 ml RBC	28.4 ± 2.4	24.2 ± 1.6	22.8 ± 2.5
Urine			
Coproporphyrin, µg/24 hr	1.2 ± 0.2	4.8 ± 2.4	2.9 ± 1.4
ALA, µg/24 hr	86.4 ± 16.6	107.6 ± 34.1	35.0 ± 6.7

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Two rats.
d/ Six rats.

TABLE 14

TISSUE AND FLUID CHEMISTRY OF RATS FED PAINT CHIPS CONTAINING NO LEAD

Analyses	Treatment Week 4 (N=8)[a]	8 (N=8)	13 (N=24)
Serum electrophoresis			
Albumin, %	43 ± 1[b]	43 ± 2	48 ± 1
Alpha 1 globulin, %	28 ± 1	23 ± 1	21 ± 1
Alpha 2 globulin, %	5 ± 1	5 ± 1	5 ± 1
Beta globulin, %	20 ± 1	20 ± 1	21 ± 1
Gamma globulin, %	6 ± 1	10 ± 1	6 ± 1
Total protein, gm %	5.4 ± 0.1	6.2 ± 0.2	6.3 ± 0.1
Albumin/globulin ratio	0.76 ± 0.03	0.77 ± 0.07	0.93 ± 0.04
Erythrocyte			
ALAD, µmol. PBG/ Males:	23.2 ± 2.3[c]	15.1 ± 2.3[c]	14.5 ± 1.4[d]
100 ml RBC/hr Females:	16.6 ± 3.1[c]	16.3 ± 2.2[c]	15.4 ± 0.7[d]
Total:	19.9 ± 2.2	15.8 ± 1.5	15.0 ± 1.0
Protoporphyrin, µg/100 ml RBC	19.6 ± 1.6	23.5 ± 1.9	29.2 ± 2.0
Urine			
Coproporphyrin, µg/24 hr	2.5 ± 1.2	3.3 ± 7.4	6.0 ± 1.9
ALA, µg/24 hr	78.0 ± 7.4	83.3 ± 11.0	43.4 ± 5.0

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Four rats.
d/ Twelve rats.

TABLE 17

TISSUE AND BODY FLUID CHEMISTRY OF RATS FED PAINT CHIPS CONTAINING 2.05% LEAD AS LEAD OCTOATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	41 ± 3[b]	46 ± 2	48 ± 2
Alpha 1 globulin, %	27 ± 2	22 ± 1	20 ± 1
Alpha 2 globulin, %	4 ± 1	4 ± 1	6 ± 1
Beta globulin, %	20 ± 1	19 ± 1	21 ± 1
Gamma globulin, %	9 ± 1	9 ± 1	6 ± 1
Total protein, gm %	5.7 ± 0.2	6.0 ± 0.1	6.2 ± 0.1
Albumin/globulin ratio	0.70 ± 0.07	0.85 ± 0.07	0.96 ± 0.07
Erythrocytes			
ALAD, µmol. PBG/ Males:	24.1 ± 4.0[c]	12.1 ± 1.7[c]	11.4 ± 0.8[d]
100 ml RBC/hr Females:	18.7 ± 1.0[c]	11.3 ± 0.2[c]	16.3 ± 3.9[d]
Total:	21.4 ± 2.3	11.7 ± 0.7	13.8 ± 2.0
Protoporphyrin, µg/100 ml RBC	29.5 ± 2.8	30.8 ± 2.5	24.0 ± 2.2
Urine			
Coproporphyrin, µg/24 hr	1.6 ± 0.6	3.0 ± 0.8	7.7 ± 2.9
ALA, µg/24 hr	80.7 ± 17.3	82.7 ± 10.4	64.5 ± 8.8

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Two rats.
d/ Six rats.

TABLE 16

TISSUE AND BODY FLUID CHEMISTRY OF RATS FED CHIPS CONTAINING 0.53% LEAD AS LEAD OCTOATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	41 ± 2[b]	41 ± 4	50 ± 1
Alpha 1 globulin, %	26 ± 1	23 ± 3	20 ± 1
Alpha 2 globulin, %	5 ± 1	6 ± 2	4 ± 1
Beta globulin, %	21 ± 1	20 ± 1	20 ± 1
Gamma globulin, %	8 ± 1	11 ± 2	7 ± 1
Total protein, gm %	5.7 ± 0.1	6.3 ± 0.1	6.0 ± 0.1
Albumin/globulin ratio	0.68 ± 0.04	0.70 ± 0.13	1.00 ± 0.07
Erythrocytes			
ALAD, µmol. PBG/ Males:	21.4 ± 6.3[c]	10.3 ± 0.8[c]	12.5 ± 0.7[d]
100 ml RBC/hr Females:	15.5 ± 2.7[c]	15.3 ± 0.2[c]	17.0 ± 1.2[d]
Total:	18.4 ± 3.3	12.8 ± 1.5	14.7 ± 0.9
Protoporphyrin, µg/100 ml RBC	23.1 ± 1.0	21.7 ± 1.1	27.7 ± 3.3
Urine			
Coproporphyrin, µg/24 hr	10.7 ± 5.9	1.1 ± 0.6	4.9 ± 2.4
ALA, µg/24 hr	97.4 ± 19.2	101.4 ± 30.1	50.5 ± 6.6

a/ Number of rats period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Two rats.
d/ Six rats.

TABLE 19

TISSUE AND BODY FLUID CHEMISTRY OF RATS FEED PAINT CHIPS CONTAINING 1.95% LEAD AS LEAD CHROMATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	41 ± 2[b]	45 ± 1	47 ± 2
Alpha 1 globulin, %	25 ± 1	19 ± 1	19 ± 2
Alpha 2 globulin, %	4 ± 1	4 ± 1	5 ± 1
Beta globulin, %	20 ± 1	20 ± 1	23 ± 1
Gamma globulin, %	9 ± 1	11 ± 1	6 ± 1
Total protein, gm %	5.7 ± 0.1	6.20 ± 0.04	6.4 ± 0.1
Albumin/globulin ratio	0.73 ± 0.06	0.81 ± 0.04	0.94 ± 0.08
Erythrocyte			
ALAD, µmol. PBG/ Males:	29.5 ± 3.1[c]	12.3 ± 1.0[c]	13.3 ± 1.4[d]
100 ml RBC/hr Females:	20.4 ± 4.3[c]	14.7 ± 0.6[c]	12.9 ± 2.3[d]
Total:	24.9 ± 3.4	13.5 ± 0.8	13.1 ± 1.3
Protoporphyrin, µg/100 ml RBC	26.5 ± 4.7	26.8 ± 1.8	27.4 ± 1.5
Urine			
Coproporphyrin, µg/24 hr	0.9 ± 0.1	7.0 ± 6.4	4.4 ± 1.9
ALA, µg/24 hr	80.8 ± 7.2	67.7 ± 6.8	66.5 ± 17.5

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Two rats.
d/ Six rats.

TABLE 18

TISSUE AND BODY FLUID CHEMISTRY OF RATS FED PAINT CHIPS CONTAINING 0.42% LEAD AS LEAD CHROMATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	42 ± 2[b]	44 ± 2	47 ± 1
Alpha 1 globulin, %	28 ± 1	20 ± 2	22 ± 1
Alpha 2 globulin, %	4 ± 1	4 ± 1	5 ± 1
Beta globulin, %	19 ± 1	19 ± 1	21 ± 1
Gamma globulin, %	8 ± 3	12 ± 2	6 ± 1
Total protein, gm %	5.8 ± 0.2	6.0 ± 0.2	6.1 ± 0.1
Albumin/globulin ratio	0.71 ± 0.06	0.80 ± 0.08	0.90 ± 0.03
Erythrocyte			
ALAD, µmol. PBG/ Males:	23.4 ± 3.5[c]	14.1 ± 0.6[c]	15.7 ± 1.5[d]
100 ml RBC/hr Females:	13.4 ± 0.9[c]	17.4 ± 0.1[c]	16.5 ± 1.4[d]
Total:	18.4 ± 3.3	15.7 ± 1.0	16.1 ± 1.0
Protoporphyrin, µg/100 ml TBC	27.3 ± 2.8	28.3 ± 0.6	27.9 ± 2.1
Urine			
Coproporphyrin, µg/24 hr	8.2 ± 6.7	1.5 ± 0.7	6.3 ± 2.2
ALA, µg/24 hr	69.3 ± 6.6	65.2 ± 17.4	85.3 ± 31.4

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Two rats.
d/ Six rats.

TABLE 21

TISSUE AND BODY FLUID CHEMISTRY OF RATS FED PAINT CHIPS CONTAINING 66.05% LEAD AS LEAD CARBONATE

Analyses	Treatment Week 4 (N=3)[a/]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	41 ± 6	45 ± 1	47 ± 2
Alpha 1 globulin, %	27 ± 1	21 ± 2	22 ± 1
Alpha 2 globulin, %	3 ± 1	4 ± 1	5 ± 1
Beta globulin, %	21 ± 2	19 ± 1	20 ± 1
Gamma globulin, %	8 ± 2	10 ± 1	7 ± 1
Total protein, gm %	5.4 ± 0.2	6.0 ± 0.06	6.3 ± 0.1
Albumin/globulin ratio	0.73 ± 0.17	0.82 ± 0.04	0.86 ± 0.06
Erythrocyte			
ALAD, µmol. PBG/ Males:	12.3[c/]	4.4 ± 0.1[d/]	5.4 ± 1.0[e/]
100 ml RBC/hr Females:	9.1 ± 2.1[d/]	12.4 ± 0.4[d/]	7.4 ± 0.8[e/]
	10.2 ± 1.6[f/]	8.4 ± 2.3[f/]	6.4 ± 0.7[f/]
Protoporphyrin, µg/100 ml RBC	23.2 ± 0.9	20.4 ± 2.1	27.2 ± 6.8
Urine			
Coproporphyrin, µg/24 hr	2.0 ± 0.7	0.8 ± 0.3	6.7 ± 3.2
ALA, µg/24 hr	90.3 ± 27.7	72.3 ± 13.4	42.2 ± 8.8

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ One rat.
d/ Two rats.
e/ Six rats.
f/ Significantly different from control ($P < 0.05$) as shown by Dunnett's multiple-comparison test following an analysis of variance.

TABLE 20

TISSUE AND BODY FLUID CHEMISTRY OF RATS FED PAINT CHIPS CONTAINING 12.43% LEAD AS LEAD CHROMATE

Analyses	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	40 ± 2[b]	47 ± 3	46 ± 2
Alpha 1 globulin, %	27 ± 1	21 ± 1	21 ± 1
Alpha 2 globulin, %	3 ± 1	4 ± 1	5 ± 1
Beta globulin, %	22 ± 1	18 ± 1	22 ± 1
Gamma globulin, %	8 ± 1	9 ± 2	6 ± 1
Total protein, gm %	5.6 ± 0.1	6.1 ± 0.1	6.4 ± 0.1
Albumin/globulin ratio	0.68 ± 0.05	0.90 ± 0.12	0.88 ± 0.06
Erythrocyte			
ALAD, µmol. PBG/ Males:	26.4 ± 7.4[c]	16.5 ± 1.4[c]	12.6 ± 1.6[d]
100 ml RBC/hr Females:	14.3 ± 3.2[c]	13.4 ± 3.8[c]	13.7 ± 1.1[d]
Total:	20.3 ± 4.9	15.0 ± 1.9	13.1 ± 1.0
Protoporphyrin, µg/100 ml RBC	25.5 ± 1.6	24.2 ± 2.6	24.6 ± 2.0
Urine			
Coproporphyrin, µg/24 hr	2.6 ± 1.8	0.9 ± 0.1	2.6 ± 0.8
ALA, µg/24 hr	89.7 ± 19.3	78.4 ± 6.8	49.7 ± 12.5

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Two rats.
d/ Six rats.

TABLE 23

SUMMARY OF PORPHYRIN METABOLISM IN RATS FED PAINT CHIPS FOR 13 WEEKS CONTAINING DIFFERENT CONCENTRATIONS OF LEAD

Diet	N[c/]	Erythrocyte		Urinary	
		ALAD[a/] (µmol. PBG/100 ml RBC/hr)	Protoporphyrin (µg/100 ml RBC)	Coproporphyrin (µg/24 hr)	ALA[b/] (µg/24 hr)
Control	24	15.0 ± 1.0[d/]	29.2 ± 2.0	6.0 ± 1.9	43.4 ± 5.0
0.08% Lead Octoate	12	14.0 ± 1.4	22.8 ± 2.5	2.9 ± 1.4	35.0 ± 6.7
0.53% Lead Octoate	12	14.7 ± 0.9	27.7 ± 3.3	4.9 ± 2.4	50.5 ± 6.6
2.05% Lead Octoate	12	13.8 ± 2.0	24.0 ± 2.2	7.7 ± 2.9	64.5 ± 8.8
0.42% Lead Chromate	12	16.1 ± 1.0	27.9 ± 2.1	6.3 ± 2.2	85.3 ± 31.4
1.95% Lead Chromate	12	13.1 ± 1.3	27.4 ± 1.5	4.4 ± 1.9	66.5 ± 17.5
12.43% Lead Chromate	12	13.1 ± 1.0	24.6 ± 2.0	2.6 ± 0.8	49.7 ± 12.5
66.05% Lead Chromate	12	6.4 ± 0.7[e/]	27.2 ± 6.8	6.7 ± 3.2	42.2 ± 8.8
11.92% NBS Lead Paint	12	6.9 ± 0.8[e/]	26.3 ± 1.2	4.6 ± 2.1	51.3 ± 3.6

a/ δ-Aminolevulinic acid dehydrase.
b/ δ-Aminolevulinic acid.
c/ Number of rats per diet.
d/ Average ± standard error of number of rats indicated.
e/ Significantly different from control ($P < 0.05$) as shown by Dunnett's Multiple-comparison test following an analysis of variance.

TABLE 22

TISSUE AND BODY FLUID CHEMISTRY OF RATS FED NBS LEAD PAINT CONTAINING 11.92% LEAD

Analysis	Treatment Week 4 (N=4)[a]	8 (N=4)	13 (N=12)
Serum electrophoresis			
Albumin, %	52 ± 1[b]	44 ± 2	44 ± 2
Alpha 1 globulin, %	21 ± 1	21 ± 2	24 ± 1
Alpha 2 globulin, %	4 ± 1	8 ± 5	7 ± 1
Beta globulin, %	20 ± 1	21 ± 3	21 ± 1
Gamma globulin,%	3 ± 1	6 ± 1	5 ± 1
Total protein, gm %	5.4 ± 0.2	6.0 ± 0.2	6.1 ± 0.1
Albumin/globulin ratio	1.1 ± 0.03	0.78 ± 0.06	0.82 ± 0.06
Erythrocyte			
ALAD, µmol. PBG/ Males:	8.5 ± 5.0[c]	5.0 ± 0.3[c]	4.9 ± 0.6[d]
100 ml RBC/hr Females:	10.1 ± 0.1[c]	15.0 ± 5.1[c]	8.8 ± 1.0[d]
Total:	9.3 ± 2.1[e]	10.0 ± 3.6	6.9 ± 0.8[e]
Protoporphyrin, µg/100 ml RBC	14.8 ± 4.3	24.5 ± 1.8	26.3 ± 1.2
Urine			
Coproporphyrin, µg/24 hr	2.0 ± 0.8	6.8 ± 4.9	4.6 ± 2.1
ALA, µg/24 hr	110.1 ± 21.5	72.0 ± 13.6	51.3 ± 3.6

a/ Number of rats per period, except where indicated otherwise.
b/ Mean ± standard error.
c/ Two rats.
d/ Six rats.
e/ Significantly different from control ($P < 0.05$) as indicated by Dunnett's multiple-comparison test following an analysis of variance.

TABLE 24

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING NO LEAD

		Treatment Week		
		4	8	13
Protein:	Negative	7	6	20
	< 100 mg %	1	2	4
	≥ 100 mg %			
Microscopic Examination				
RBC[a]:	Normal	7	5	23
	Moderate	1	2	1
	Excessive		1	
WBC[a]:	Normal	6	7	21
	Moderate	2		2
	Excessive		2	1
Epithelium[b]:	Normal	8	8	24
	Moderate			
	Excessive			
Crystals[c]:	Normal	4	8	23
	Moderate	2		1
	Excessive	2		
Casts:	Negative	8	8	24
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

By 13 weeks the sex difference had disappeared and the ALAD activity in 66.05% lead carbonate group and the 11.92% NBS lead paint group were depressed 56% and 53%, respectively.

Urinalysis of rats fed paint chips containing different concentrations of lead are shown in Table 24-32. No marked differences in urinary protein or sediment (erythrocyte, crystals, casts, etc.) were seen in the control, lead octoate, lead chromate and lead carbonate groups. In the NBS lead paint group 5 of 12 rats (42%) had a moderate proteinuria compared with only 4 of 24 rats (17%) in the control group. Otherwise, the urinalysis of this group was similar to that of the control group.

H. Lead Content in Tissues of Rats Fed Paint Chips Containing Different Concentrations of Lead

Tables 33-37 show the lead content of blood, brain, liver, kidney, and bone from rats fed paint chips containing different concentrations of lead. All values for the lead concentrations in blood at 4 and 8 weeks, and 4 values in all but the NBS lead paint group at 13 weeks were omitted from Table 33 because it was discovered that these samples had been contaminated by their storage containers. The blood lead levels of rats fed paint chips containing lead octoate (0.08%, 0.53%, 2.05%) or lead chromate (0.42%, 1.95%) were no higher than control. In the rats fed paint chips containing 12.43% lead chromate or 66.05% lead carbonate, or the 11.92% NBS lead paint (lead carbonate) blood lead levels were found to be elevated significantly.

At 4 weeks, tissue lead levels in brain, liver and kidney were below the detection limits of our assay (0.7 μg per gm of tissue). The results were the same at 8 weeks with the exception of the NBS lead paint group. All four rats in this group showed detectable lead in their kidneys.

At 13 weeks, detectable levels of lead in the brain appeared only in the rats fed 11.92% NBS lead paint. In the liver, detectable levels of lead were found in two rats fed 66.05% lead carbonate paint chips and nine rats fed 11.92% NBS lead paint. No lead was detected in the kidneys of the control group at 13 weeks. In contrast, lead was detected in the kidneys of one to two rats in each lead octoate group and the 0.42% and 1.95% lead chromate groups. Lead was detected in the kidneys of three rats, eight rats and 12 rats in the 12.43% lead chromate paint, 66.05% lead carbonate paint, and 11.95% NBS lead paint groups, respectively.

The femurs of rats fed the control diet, lead octoate or lead chromate paints exhibited very little lead at 4 weeks. However, the femurs of rats fed 66.05% lead carbonate or 11.92% NBS lead paint contained 13.0 and 14.9 μg of lead/gm of bone, respectively.

TABLE 26

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 0.53% LEAD AS LEAD OCTOATE

		Treatment Week 4	8	13
Protein:	Negative	4	3	10
	< 100 mg %		1	1
	≥ 100 mg %			1
Microscopic Examination				
RBC[a]:	Normal	2	2	10
	Moderate	1	2	1
	Excessive	1		1
WBC[a]:	Normal	4	1	9
	Moderate		3	3
	Excessive			
Epithelium[b]:	Normal	4	4	12
	Moderate			
	Excessive			
Crystals[c]:	Normal	3	4	12
	Moderate	1		
	Excessive			
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 25

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 0.08% LEAD AS LEAD OCTOATE

		Treatment Week		
		4	8	13
Protein:	Negative	4	3	8
	< 100 mg %			4
	≥ 100 mg %		1	
Microscopic Examination				
RBC[a]:	Normal	4	3	10
	Moderate		1	2
	Excessive			
WBC[a]:	Normal	2	3	10
	Moderate	2	1	2
	Excessive			
Epithelium[b]:	Normal	4	4	12
	Moderate			
	Excessive			
Crystals[c]:	Normal	2	4	11
	Moderate	2		1
	Excessive			
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 28

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 0.42% LEAD AS LEAD CHROMATE

		Treatment Week		
		4	8	13
Protein:	Negative	4	2	10
	< 100 mg %		2	1
	≥ 100 mg %			1
Microscopic Examination				
RBC[a/]:	Normal	3	1	8
	Moderate	1	3	3
	Excessive			1
WBC[a/]:	Normal	2	3	8
	Moderate	2	1	1
	Excessive			3
Epithelium[b/]:	Normal	4	4	12
	Moderate			
	Excessive			
Crystals[c/]:	Normal	2	4	12
	Moderate	1		
	Excessive	1		
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 27

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 2.05% LEAD AS LEAD OCTOATE

		Treatment Week		
		4	8	13
Protein:	Negative	4	4	11
	< 100 mg %			1
	> 100 mg %			
Microscopic Examination				
RBC[a]:	Normal	4	4	12
	Moderate			
	Excessive			
WBC[a]:	Normal	3	3	8
	Moderate	1		4
	Excessive		1	
Epithelium[b]:	Normal	4	4	12
	Moderate			
	Excessive			
Crystals[c]:	Normal	2	4	12
	Moderate			
	Excessive	2		
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 30

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 12.43% LEAD AS LEAD CHROMATE

		Treatment Week		
		4	8	13
Protein:	Negative	1	1	9
	< 100 mg %	3	2	3
	≥ 100 mg %		1	
Microscopic Examination				
RBC[a]:	Normal	4	1	11
	Moderate			1
	Excessive		3	
WBC[a]:	Normal	1	1	11
	Moderate	3	1	
	Excessive		2	1
Epithelium[b]:	Normal	4	4	11
	Moderate			1
	Excessive			
Crystals[c]:	Normal	2	4	12
	Moderate	2		
	Excessive			
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 29

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 1.95% LEAD AS LEAD CHROMATE

		Treatment Week		
		4	8	13
Protein:	Negative	3	3	11
	< 100 mg %	1		1
	> 100 mg %		1	
Microscopic Examination				
RBC[a]:	Normal	4	3	12
	Moderate		1	
	Excessive			
WBC[a]:	Normal	2	3	8
	Moderate	2		3
	Excessive		1	1
Epithelium[b]:	Normal	4	4	12
	Moderate			
	Excessive			
Crystals[c]:	Normal	4	4	12
	Moderate			
	Excessive			
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 32

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 11.92% LEAD (NBS LEAD PAINT)

		Treatment Week		
		4	8	13
Protein:	Negative	2	3	7
	< 100 mg %	2		5
	≥ 100 mg %		1	
Microscopic Examination				
RBC[a]:	Normal	2	4	12
	Moderate	2		
	Excessive			
WBC[a]:	Normal	2	3	11
	Moderate		1	1
	Excessive	2		
Epithelium[b]:	Normal	4	4	12
	Moderate			
	Excessive			
Crystals[c]:	Normal	4	4	12
	Moderate			
	Excessive			
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 31

URINALYSIS OF RATS FED PAINT CHIPS CONTAINING 66.05% LEAD AS LEAD CARBONATE

		Treatment Week		
		4	8	13
Protein:	Negative	3	4	11
	< 100 mg %	1		1
	≥ 100 mg %			
Microscopic Examination				
RBC[a]:	Normal	4	2	11
	Moderate		2	1
	Excessive			
WBC[a]:	Normal	2	2	10
	Moderate	2	2	2
	Excessive			
Epithelium[b]:	Normal	4	4	12
	Moderate			
	Excessive			
Crystals[c]:	Normal	3	4	12
	Moderate			
	Excessive	1		
Casts:	Negative	4	4	12
	Positive			

Numbers indicate number of rats at response level.

a/ Normal, 10 or less cells; moderate, 10-100 cells; excessive, > 100 cells/field (x 440).

b/ Normal, 5 or less cells; moderate, 5-25 cells; excessive, > 25 cells/field (x 100).

c/ Normal, none; moderate, 1-5 crystals; excessive, > 5 crystals/field (x 100).

TABLE 34

LEAD CONTENT OF BRAIN

Diet	Treatment Week 4 (4)[a]	8 (4)	13 (12)
Control[b]	n.d.[c]	n.d.	n.d.
0.08% Lead Octoate	n.d.	n.d.	n.d.
0.53% Lead Octoate	n.d.	n.d.	n.d.
2.05% Lead Octoate	n.d.	n.d.	n.d.
0.42% Lead Chromate	n.d.	n.d.	n.d.
1.95% Lead Chromate	n.d.	n.d.	n.d.
12.43% Lead Chromate	n.d.	n.d.	n.d.
66.05% Lead Carbonate	n.d.	n.d.	n.d.
11.92% NBS Lead Paint	n.d.	n.d.	0.2 ± 0.1[d] (7)

a/ Number of brains analyzed per group unless indicated otherwise.
b/ Eight brains were analyzed at 4 and 8 weeks. Twenty-four brains were analyzed at 13 weeks.
c/ Not detectable. Below sensitivity of 0.07 µg/gm of brain.
d/ Average µg of lead/gm brain ± standard error number of rats shown in parenthesis.

TABLE 33

LEAD CONTENT OF WHOLE BLOOD

Diet	Treatment Week 4[a]	8[a]	13[b] (8)[c]
Control[d]			13.1 ± 0.9 (16)[e]
0.08% Lead Octoate			12.8 ± 0.8 (8)
0.53% Lead Octoate			16.4 ± 2.4 (7)[f]
2.05% Lead Octoate			14.5 ± 1.5 (8)
0.42% Lead Chromate			13.2 ± 1.0 (8)
1.95% Lead Chromate			12.0 ± 1.4 (8)
12.43% Lead Chromate			19.4 ± 2.2 (8)[g]
66.05% Lead Carbonate			24.9 ± 2.2 (8)[g]
11.92% NBS Lead Paint			23.9 ± 1.3 (12)[g,h]

a/ Values deleted due to contamination.
b/ Four samples were omitted due to contamination.
c/ Number of rat bloods analyzed per group unless indicated otherwise.
d/ Sixteen blood samples were analyzed.
e/ Average µg of lead/100 ml blood ± standard error of number of rats in parenthesis.
f/ One blood sample lost.
g/ Significantly different from control ($P < 0.05$) as shown by Dunnett's multiple-comparison test following an analysis of variance.
h/ Twelve blood samples analyzed.

TABLE 36

LEAD CONTENT OF KIDNEY

Diet	Treatment Week 4 (4)[a]	8 (4)	13 (12)
Control[b]	n.d.[c]	n.d.	n.d.
0.08% Lead Octoate	n.d.	n.d.	0.3 (1)
0.53% Lead Octoate	n.d.	n.d.	0.3 (1)
2.05% Lead Octoate	n.d.	n.d.	0.4 ± 0.1 (2)
0.42% Lead Chromate	n.d.	n.d.	0.5 (1)
1.95% Lead Chromate	n.d.	n.d.	4.2[d] (1)
12.43% Lead Chromate	n.d.	n.d.	0.4 ± 0.0 (3)
66.05% Lead Carbonate	n.d.	n.d.	2.3 ± 0.2 (8)
11.92% NBS Lead Paint	n.d.	1.4 ± 0.1[e] (4)	1.9 ± 0.1 (12)

a/ Number of kidneys analyzed per group unless otherwise indicated.
b/ Eight kidneys were analyzed at 4 and 8 weeks. Twenty-four kidneys were analyzed at 13 weeks.
c/ Not detectable. Below sensitivity of 0.07 µg/gm kidney.
d/ No explanation for unusually high value.
e/ Values are µg of lead/gm kidney or average µg of lead/gm kidney ± standard error of number of rats in parenthesis.

LEAD CONTENT OF LIVER

Diet	Treatment Week 4 (4)[a]	8 (4)	13 (12)
Control[b]	n.d.[c]	n.d.	n.d.
0.08% Lead Octoate	n.d.	n.d.	n.d.
0.53% Lead Octoate	n.d.	n.d.	n.d.
2.05% Lead Octoate	n.d.	n.d.	n.d.
0.42% Lead Chromate	n.d.	n.d.	n.d.
1.95% Lead Chromate	n.d.	n.d.	n.d.
12.43% Lead Chromate	n.d.	n.d.	n.d.
66.05% Lead Carbonate	n.d.	n.d.	1.1 ± 0.6[d] (2)
11.92% NBS Lead Paint	n.d.	n.d.	0.4 ± 0.1 (9)

a/ Number of livers analyzed per group unless indicated otherwise.

b/ Eight livers were analyzed at 4 and 8 weeks. Twenty-four livers were analyzed at 13 weeks.

c/ Not detectable. Below sensitivity of 0.07 µg/gm liver.

d/ Values are average µg of lead/gm liver ± standard error of number of rats shown in parenthesis.

At 8 weeks, the femurs of rats fed the control, lead octoate or lead chromate diets contained similar quantities of lead, ranging from 1.8 - 4.2 μg lead/gm bone. Lead content in the femurs in the 66.05% lead carbonate and 11.92% NBS groups were 16.0 and 16.4 μg of lead/gm of bone, respectively. Both of these values were significantly above control.

After 13 weeks, the rats fed lead octoate or lead chromate had no more lead in their femurs than at 8 weeks and these levels were no higher than those in the control group. The 66.05% lead carbonate group exhibited higher levels of lead in their femurs (21.7 μg lead/gm bone) than at 8 weeks. The 11.92% NBS lead paint group had less lead in their femurs (10.9 μg lead/gm bone) than at 8 weeks. The lead levels in both of these groups were significantly greater than those observed in the control rats.

I. Pathology of Rats Fed Paint Chips Containing Different Concentrations of Lead

The relative organ weights of the thyroid, spleen, heart, kidneys, liver, adrenals, brain and gonads are shown in Table 38. The Dunnett's multiple-comparison test showed that none of the relative organ weights differed from control values.

The pathology of rats fed the control, 2.05% lead octoate, 12.43% lead chromate, 66.05% lead carbonate or 11.92% NBS lead paint diets for 13 weeks is shown in Tables 39-43.

The control rats had a few naturally occurring lesions. Fourteen of the twenty-four (58.390) rats had mild to moderate lymphoid hyperplasia in the lungs, characteristic of early minute pneumonia. One of these rats had a moderate pneumonia and another one a mild emphysema. Other lesions included an unspecific myocarditis in two rats; foci of subacute inflammation in the liver of two rats; a cross-section of a parasite (roundworm) in the colon of one rat; and foci of mononuclear cell infiltration in the kidneys of two rats. The bone marrow myeloid/erythroid cell ratios (M/E) of all rats were within normal limits.

The lesions observed in rats fed the 2.05% lead octoate diet were similar to the lesions seen in the control rats. Seven out of the 12 rats (58.3%) had mild to moderate lymphoid hyperplasia in the lungs and one had mild pneumonia. Four rats had mild foci of subacute inflammation in the liver characterized by a loss of several hepatic cord cells which were replaced by macrophages and lymphocytes. Another rat had a focus of inflammation in the interstitial tissue of the pancreas. The M/E ratios of these rats were normal.

TABLE 37

LEAD CONTENT OF BONE (FEMUR)

Diet	Treatment Week 4 (4)[a]	8 (4)	13 (12)
Control[b]	1.6[c] (1)	3.9 ± 0.4 (8)	3.2 ± 0.2 (24)
0.08% Lead Octoate	3.1 (1)	4.2 ± 0.6 (4)	3.3 ± 0.3 (12)
0.53% Lead Octoate	n.d.[d]	3.9 ± 0.2 (4)	3.1 ± 0.2 (12)
2.05% Lead Octoate	n.d.	3.0 ± 0.7 (4)	3.9 ± 0.5 (12)
0.42% Lead Chromate	2.9 (1)	2.6 ± 0.9 (4)	3.8 ± 0.6 (12)
1.95% Lead Chromate	0.9 (1)	1.8 ± 0.2 (4)	4.1 ± 0.5 (12)
12.43% Lead Chromate	3.3 (1)	3.1 ± 1.1 (4)	3.5 ± 0.5 (10)[e]
66.05% Lead Carbonate	13.0 ± 4.1 (4)	16.0 ± 2.1 (4)[f]	21.7 ± 2.4 (12)[f]
11.92% NBS Lead Paint	14.9 ± 1.5 (4)	16.4 ± 0.4 (4)[f]	10.9 ± 0.9 (12)[f]

[a] Number of bones analyzed per group unless indicated otherwise.
[b] Eight bones were analyzed at 4 and 8 weeks. Twenty-four bones were analyzed at 13 weeks.
[c] Values are μg of lead/gm bone or average μg of lead/gm bone ± standard error of number of rats in parenthesis.
[d] Not detectable. Below sensitivity of 0.4 μg/gm of bone.
[e] Two samples lost
[f] Significantly different from control ($P < 0.05$) as shown by Dunnett's multiple comparison test following an analysis of variance.

TABLE 39

PATHOLOGY OF RATS FED FOR 13 WEEKS WITH PAINT CHIPS CONTAINING NO LEAD

Rat No.	3	6	7	8	9	10	13	16	17	18	19	20	23	26	27	28	29	30	33	36	3
Lungs																					
Lymphoid hyperplasia	2a/			2	1	1			1			2	1				1		1	1	
Pneumonia																	2				
Emphysema				1																	
Heart																					
Myocarditis				1											2						
Liver																					
Foci of Inflammation								1										1			
Colon																					
Parasites (round worms)																		1			
Kidneys																					
Mononuclear cell Infiltration											2										
Bone Marrow																					
M/E ratio	1.2	1.2	1.3	1.2	1.4	1.4	1.0	1.0	1.2	1.1	1.2	1.2	1.2	1.3	1.2	1.0	1.5	1.5	1.0	1.3	1.

Tissues not listed were normal.

a/ Severity of lesions; 1-minimal; 2-moderate; 3-severe; 4-very severe; ± questionable

TABLE 38

RELATIVE ORGAN WEIGHTS OF RATS FED DIETS CONTAINING DIFFERENT CONCENTRATIONS OF LEAD IN PAINT CHIPS FOR 13 WEEKS

Diet	(N)	Thyroid mg/100gm Body Weight	Spleen gm/100gm Body Weight	Heart gm/100gm Body Weight	Kidneys gm/100gm Body Weight	Liver gm/100gm Body Weight	Organs with sex difference				
							(N)	Adrenals mg/100gm Body Weight		Brain gm/100gm Body Weight	
								Male	Female	Male	Female
Control	24	6.15 ± 0.32[a/]	0.16 ± 0.01	0.28 ± 0.01	0.66 ± 0.01	3.08 ± 0.08	12	12.05 ± 0.79	28.75 ± 1.17	0.43 ± 0.01	0.70 ± 0.02
0.08% Lead Octoate	12	6.28 ± 0.53	0.17 ± 0.01	0.28 ± 0.01	0.65 ± 0.01	2.92 ± 0.10	6	12.93 ± 0.49	27.76 ± 1.00	0.44 ± 0.01	0.70 ± 0.02
0.53% Lead Octoate	12	6.51 ± 0.44	0.17 ± 0.01	0.28 ± 0.01	0.67 ± 0.02	3.12 ± 0.21	6	12.79 ± 0.91	27.54 ± 1.00	0.45 ± 0.03	0.71 ± 0.02
2.05% Lead Octoate	12	6.73 ± 0.67	0.17 ± 0.02	0.28 ± 0.01	0.66 ± 0.01	3.12 ± 0.09	6	12.30 ± 0.97	26.44 ± 1.66	0.44 ± 0.01	0.76 ± 0.02
0.42% Lead Chromate	12	6.10 ± 0.38	0.16 ± 0.01	0.28 ± 0.01	0.66 ± 0.02	3.11 ± 0.09	6	11.43 ± 0.94	27.74 ± 1.74	0.41 ± 0.02	0.71 ± 0.01
1.95% Lead Chromate	12	5.57 ± 0.55	0.16 ± 0.01	0.28 ± 0.01	0.65 ± 0.02	3.14 ± 0.09	6	12.86 ± 1.03	25.77 ± 1.09	0.42 ± 0.01	0.66 ± 0.03
12.43% Lead Chromate	12	6.18 ± 0.49[b/]	0.16 ± 0.01	0.28 ± 0.01	0.64 ± 0.01	3.20 ± 0.07	6	11.24 ± 0.32	25.46 ± 1.08	0.43 ± 0.02	0.69 ± 0.02
66.05% Lead Carbonate	12	7.79 ± 0.67	0.21 ± 0.03	0.29 ± 0.01	0.70 ± 0.02	3.12 ± 0.12	6	14.85 ± 1.55	30.83 ± 1.66	0.45 ± 0.02	0.72 ± 0.04
11.92% Lead Paint	12	6.20 ± 0.46	0.18 ± 0.01	0.27 ± 0.01	0.65 ± 0.01	3.24 ± 0.05	6	12.77 ± 0.44	25.51 ± 1.25	0.44 ± 0.02	0.68 ± 0.02

a/ Average ± standard error of number (N) of rats indicated.
b/ Eleven rats.

TABLE 41

PATHOLOGY OF RATS FED FOR 13 WEEKS WITH PAINT CHIPS CONTAINING 12.43% LEAD AS LEAD CHROMATE

Rat No.	143	146	147	148	149	150	153	156	157	158
Lungs										
Lymphoid hyperplasia	2[a/]	2		1		1				2
Pneumonia	1									
Heart										
Myocarditis		2								
Bone Marrow										
M/E ratio	1.2	1.0	1.0	1.2	1.1	1.4	1.1	1.4	1.5	1.4

Tissues not listed were normal.

a/ Severity of lesions: 1-minimal; 2-moderate; 3-severe; 4-very severe; ± questionable.

TABLE 40

PATHOLOGY OF RATS FED FOR 13 WEEKS WITH PAINT CHIPS CONTAI
2.05% LEAD AS LEAD OCTOATE

	83	86	87	88	89	90	93	96	97	98	99
Lungs											
Lymphoid hyperplasia					1[a/]	2	1	1		1	2
Pneumonia					1						
Liver											
Foci of inflammation	1			1				1			
Pancreas											
Foci of inflammation		1									
Bone Marrow											
M/E ratio	1.2	1.0	1.7	1.0	1.2	1.1	1.1	1.1	1.4	1.2	1.3

Tissues not listed were normal.

a/ Severity of lesions: 1-minimal; 2-moderate; 3-severe; 4-very severe; ± questionable

TABLE 43

PATHOLOGY OF RATS FED FOR 13 WEEKS WITH NBS LEAD PAINT CHIPS CONTAINING 11.92% LEAD

Rat No.	183	184	185	188	189	190	193	194	195	198	199	200
Lungs												
Lymphoid hyperplasia	2[a]	2		2		2			1	2	1	2
Pneumonia				2								
Heart												
Myocarditis			2		1							
Liver												
Foci of inflammation									1			
Bone Marrow												
M/E ratio	1.2	1.4	1.3	1.2	1.5	1.2	1.2	1.4	1.5	1.3	1.2	1.3

Tissues not listed were normal.

a/ Severity of lesions: 1-minimal; 2-moderate; 3-severe; 4-very severe; ± questionable

TABLE 42

PATHOLOGY OF RATS FED FOR 13 WEEKS WITH PAINT CHIPS CONTAINING 66.05% LEAD AS LEAD CARBONATE

Rat No.	163	166	167	168	169	170	173	176	177	178
Lungs										
Lymphoid hyperplasia		1[a/]	1	1		1			2	
Pneumonia						1				
Heart										
Myocarditis		1	2		1					
Liver										
Foci of inflammation	1		1							
Skeletal muscle										
Miositis			1							
Bone Marrow										
M/E ratio	1.2	1.2	1.2	1.0	1.1	1.3	1.2	1.0	1.4	1.3

Tissues not listed were normal.

a/ Severity of lesions: 1-minimal; 2-moderate; 3-severe; 4-very severe; ± questionable

The body lead burden of rats fed paint containing lead octoate or lead chromate was no different from control until 13 weeks. At this time lead was found in the kidneys of one to three rats on each of the lead octoate and lead chromate diets. The rats with measurable kidney lead in the lead octoate, 0.42% lead chromate or 1.95% lead chromate groups did not have concominant increases in blood, brain, liver or bone lead. Thus, these rats did not have a significant increase in body lead-burden. On the other hand, the rats fed the 12.43% lead chromate diet had elevated blood lead and thus, a significant elevation of body lead-burden. Since rats fed lead nitrate show elevated lead levels in blood, kidneys, bone and liver within 2 weeks,[13] it appears that the lead octoate and lead chromate were either not readily absorbed or not otherwise available for absorption.

Complete gross and microscopic pathology was performed on the rats that were fed the control, 2.05% lead octoate, 12.43% lead chromate, and 11.92% NBS lead paint diets for 13 weeks. All of these rats were relatively free of lesions, and those lesions which were observed, occur naturally in rat colonies.

CONCLUSIONS

Older paint formulations contained soluble lead salts. Two samples of paint chips representative of these formulations were fed to rats at 0.1% of their diets. One was supplied by the National Bureau of Standards and was removed from interior walls of older homes. It contained 11.92% lead. The other was a recent formulation containing 66.05% lead carbonate. Both of these samples produced classical signs of lead poisoning in the rats. These signs consisted of erythrocyte ALAD depression (50%) and significant increases in blood, kidney, bone, liver and/or brain lead.

Newer paint formulations contain insoluble lead pigments and low levels of lead driers. Several samples of paint chips containing up to 12.43% lead chromate pigment and up to 2.0% lead octoate drier were also fed to rats as 0.1% of their diets. The only evidence of toxicity or effect on body burden appear in the rats fed the paint containing 12.43% lead chromate. This consisted of an increase in blood lead, without other signs of poisoning. Paint containing 1.95% lead chromate and paint containing 2.05% lead octoate produced no detectable changes in the rats.

The quantity of lead fed as paint chips containing either 2.05% lead octoate or 1.95% lead chromate would have approximated an intake of 40 mg/day in a 3 year old child weighing 14.6 kilograms. This daily intake has been reported to produce lead poisoning in children if the lead was available for absorption. Since the body lead-burdens of the rats fed 2.05% lead octoate or 1.95% lead chromate were not increased, it can be assumed that the lead in these paint chips was not absorbed from the gastrointestinal tract. In addition, lead in paint scraped from old dwellings and not the newly formulated paint, deposited in the brain, even though the blood lead concentrations of both were similar.

The rats fed the 12.43% lead chromate diet had lesions similar to the lesions seen in the control rats. Seven of 12 rats (58.3%) had mild to moderate lymphoid hyperplasia, and one had mild pneumonia. Only one rat had a moderate unspecific myocarditis. The M/E ratios were normal.

The lesions seen in the rats fed the 11.92% NBS lead paint diet were similar to those lesions seen in the control rats. Eight of 12 rats (66.7%) had different degrees of lymphoid hyperplasia in the lungs. In one rat pneumonia was evident. Unspecific myocarditis occurred in 2 rats while foci of inflammation in the liver were observed in only one rat. The M/E ratios were normal.

In conclusion, the pathology seen in the control and treated rats were characteristic of those in a normal population of rats. No evidence of lead-induced lesions was found.

IV. DISCUSSION

The levels of lead fed to rats in the study were sufficient to produce significant elevation of body lead burden if the lead is in the form of lead nitrate.[13] If we equate the amount of lead consumed by the average rat fed paint chips containing 2.05% lead octoate, 12.43% lead chromate, 66.05% lead carbonate, and 11.92% NBS lead paint diets to a 14.6 kg (3-year old) child, we find that the lead consumption would equal 39.4, 156.0, 577.8, and 147.8 mg of lead/day, respectively. On the basis of a 2% lead paint, the total paint intake would be 2.0, 7.8, 28.9, and 7.4 gm/day respectively. Daily ingestion of these quantities of old paint containing white lead have been reported to produce lead poisoning.[13]

There were no changes in hematology, urinalysis or serum proteins in the rats fed lead octoate, lead chromate or lead carbonate. The rats fed the NBS lead paint did exhibit a significant reduction in hemaglobin and a mild proteinuria at 13 weeks. Otherwise, the hematology, urinalysis and serum proteins in the rats fed NBS lead paint were normal. Porphrin metabolism was affected as early as 4 weeks in rats fed either the 66.05% lead carbonate diet or the 11.92% NBS lead paint diet as evidenced in a 50% depression of erythrocyte ALAD activity. This effect appeared to be directly related to the concentration of blood lead as has been reported by others.[14,15] There was one exception: blood lead in the 12.43% lead chromate group became elevated by the 13th week, but there was no depression of ALAD activity. This discrepancy could be related to the duration of elevated blood lead or the age of the animal when blood lead became elevated.

Even though erythrocyte ALAD was depressed 50%, the overall effect on porphyrin metabolism must be considered mild, since there was no concomitant change in the levels of protoporphyrin (erythrocyte), delta-aminolevulinic acid and coproporphyrin. These observations are consistent with reports that blood lead levels greater than 40 µg/100 ml RBC are needed before serious changes in porphyrin metabolism occur.[14]

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