RESIDUE REVIEWS

VOLUME 48

RESIDUE REVIEWS

Residues of Pesticides and Other
Contaminants in the Total Environment

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Preface

That residues of pesticide and other contaminants in the total environment are of concern to everyone everywhere is attested by the reception accorded previous volumes of "Residue Reviews" and by the gratifying enthusiasm, sincerity, and efforts shown by all the individuals from whom manuscripts have been solicited. Despite much propaganda to the contrary, there can never be any serious question that pest-control chemicals and food-additive chemicals are essential to adequate food production, manufacture, marketing, and storage, yet without continuing surveillance and intelligent control some of those that persist in our foodstuffs could at times conceivably endanger the public health. Ensuring safety-in-use of these many chemicals is a dynamic challenge, for established ones are continually being displaced by newly developed ones more acceptable to food technologists, pharmacologists, toxicologists, and changing pest-control requirements in progressive food-producing economies.

These matters are of genuine concern to increasing numbers of governmental agencies and legislative bodies around the world, for some of these chemicals have resulted in a few mishaps from improper use. Adequate safety-in-use evaluations of any of these chemicals persisting into our foodstuffs are not simple matters, and they incorporate the considered judgments of many individuals highly trained in a variety of complex biological, chemical, food technological, medical, pharmacological, and toxicologial disciplines.

It is hoped that "Residue Reviews" will continue to serve as an integrating factor both in focusing attention upon those many residue matters requiring further attention and in collating for variously trained readers present knowledge in specific important areas of residue and related endeavors involved with other chemical contaminants in the total environment. The contents of this and previous volumes of "Residue Reviews" illustrate these objectives. Since manuscripts are published in the order in which they are received in final form, it may seem that some important aspects of residue analytical chemistry, biochemistry, human and animal medicine, legislation, pharmacology, physiology, regulation, and toxicology are being neglected; to the contrary, these apparent omissions are recognized, and some pertinent manuscripts are in preparation. However, the field is so large and the interests in it are so varied that the editors and the Advisory Board earnestly solicit suggestions of topics and authors to help make this international book-series even more useful and informative.

"Residue Reviews" attempts to provide concise, critical reviews of timely advances, philosophy, and significant areas of accomplished or needed endeavor in the total field of residues of these and other foreign chemicals in any segment of the environment. These reviews are either general or specific, but properly they may lie in the domains of analytical chemistry and its methodology, biochemistry, human and animal medicine, legislation, pharmacology, physiology, regulation, and toxicology; certain affairs in the realm of food technology concerned specifically with pesticide and other food-additive problems are also appropriate subject matter. The justification for the preparation of any review for this book-series is that it deals with some aspect of the many real problems arising from the presence of any "foreign" chemicals in our surroundings. Thus, manuscripts may encompass those matters, in any country, which are involved in allowing pesticide and other plant-protecting chemicals to be used safely in producing, storing, and shipping crops. Added plant or animal pest-control chemicals or their metabolites that may persist into meat and other edible animal products (milk and milk products, eggs, etc.) are also residues and are within this scope. The so-called food additives (substances deliberately added to foods for flavor, odor, appearance, etc., as well as those inadvertently added during manufacture, packaging, distribution, storage, etc.) are also considered suitable review material. In addition, contaminant chemicals added in any manner to air, water, soil, or plant or animal life are within this purview and these objectives.

Manuscripts are normally contributed by invitation but suggested topics are welcome. Preliminary communication with the editors is necessary before volunteered reviews are submitted in manuscript form.

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July 26, 1973

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Table of Contents

Cadmium residues in the environment

By

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Contents

I. Introduction

Cadmium (Cd) is a potentially hazardous pollutant in the environment based upon observations of increasing emissions from production and waste-disposal operations, long-term persistence in the environment, and rapid uptake and accumulation of injurious concentrations by plants and animals. Chronic human exposure to low concentrations of cadmium in the atmosphere, water, or food may cause serious illness and possibly death. Production and consumption of cadmium is continuing to expand throughout the industrialized world. As a result, there is a critical need for understanding sources of emissions and their direct or indirect interactions with soil, water, plants, and animals so that criteria may be developed for assessing hazards.

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II. Natural occurrence

Cadmium is a relatively rare metal not found in a pure state in nature. It is unique in that no mines or ores are worked for its sole production. It was discovered in 1817 as a constituent of smithsonite ($ZnCO_3$) obtained from a zinc ore by a German chemist, F. Strohmeyer. Cadmium is closely related to zinc and is found mainly in zinc, lead-zinc, and lead-copper-zinc ores. The concentration of cadmium in these ores is usually related to their zinc content and increases as the content of zinc increases. The amount in the principal zinc ore, zinc blende (ZnS), varies over wide limits from a low of about 0.1 to a high of five percent and sometimes higher (CHIZHIKOV 1966). Commonly, the content of cadmium in zinc concentrates ranges from 0.2 to 0.4 percent, and rarely do zinc concentrates contain more than one percent cadmium (SNEED and BRASTED 1955). The cadmium content of the majority of copper-zinc deposits is 0.3 part of cadmium/100 parts of zinc and for lead-zinc deposits 0.4 part of cadmium/100 parts of zinc (CHIZHIKOV 1966).

The average concentration of cadmium in the earth's crust is 0.15 p.p.m. (WEAST 1969). In terms of relative abundance, 14 elements—silver, indium, selenium, argon, palladium, platinum, gold, helium, tellurium, rhodium, rhenium, iridium, osmium, and ruthenium—occur in lesser concentrations in the earth's crust. WAKETA and SCHMITT (1970) recently compiled the published data for the cadmium content of certain rock-forming minerals. Amounts found in Plagioclase, Olivine, Magnetite, Illmenite, Pyroxene, and Apatite from Greenland ranged between 0.12 and 0.37 p.p.m. Five samples of biotite from biotite-granite in northern Nigeria contained between 0.16 and 4.8 p.p.m. with an average content of 1.51 p.p.m. Samples of Albite and Glauconite contained less than 0.03 p.p.m of cadmium. Sphalerites from Sweden, the Soviet Union, the United States, and Vietnam, in general contained between 500 and 18,500 p.p.m. of cadmium.

The ranges and mean concentrations of cadmium for some common igneous, sedimentary, and metamorphic rocks, condensed from data cited by WAKETA and SCHMITT (1970), are given in Table I. Igneous and metamorphic rocks rarely contain more than one p.p.m. Cadmium contents of sedimentary rocks range between a few tenths and ten p.p.m. Certain shales are abnormally high in cadmium. WEDEPOHL (1968) gives a normal concentration in shales as 0.8 p.p.m.

Amounts of cadmium in marine sediments in the Atlantic and Pacific Oceans range between 0.1 and 1.0 p.p.m. (MULLIN and RILEY 1956). Manganese marine nodules and marine phosphorites are unusually high in cadmium. MULLIN and RILEY (1956) report 5.1 and 8.4 p.p.m. for manganese nodules from the Pacific Ocean, and concentrations of about 100 p.p.m. are reported for certain marine zinc-bearing phosphorites from the Oceanic Islands (GOLDSCHMIDT 1958).

Table I. *Abundance of cadmium in common rocks.*[a]

Rock type	Cadmium (p.p.m.) Range	Mean	No. samples
Igneous			
Granite	0.001–0.60	0.12	44
Granodiorite	0.016–0.10	0.07	5
Biotite-Granite	<0.05–0.50	—	9
Quartz Monzonite	1.4–1.8	—	—
Pitchstone	0.05–0.34	0.17	24
Rhyolite	0.05–0.48	—	8
Obsidian	0.22–0.29	0.25	2
Andesite	—	0.017	2
Syenite	0.04–0.32	0.16	6
Basalt	0.006–0.6	0.22	39
Gabbro	0.08–0.20	0.11	8
Sedimentary			
Bituminous Shale	<0.3–11	0.80	84
Bentonite	<0.3–11	1.4	10
Marlstone	0.4–10	2.6	8
Shale and Claystone	<0.3–8.4	1.0	66
Limestone	—	0.035	—
Metamorphic			
Eclogite	0.04–0.26	0.11	6
Garnet Schist	—	1.0	—
Grey Gneiss	0.12–0.16	0.14	2

[a] Condensed from data cited by WAKETA and SCHMITT (1970).

III. World production

The first-mentioned production of metallic cadmium on an industrial scale occurred in what is now Poland in 1829 (CHIZHIKOV 1966). Prior to about 1870, the average annual production never exceeded 100 kg. After 1870 production gradually increased, principally from sources in Germany, and at the turn of the century approximately 20 metric tons were produced annually. Table II summarizes the world production of cadmium for ten-year periods commencing in 1910. Prior to 1910, the total amount of cadmium produced in the world was about 400 metric tons (CHIZHIKOV 1966). Production commenced in the United States in 1907 when six metric tons were produced. Germany was the principal producer of cadmium until 1916. Since that time, the United States has led the world in its production. During the 1940s the United States produced approximately 70 percent of the world's supply (Table II). Commencing in the 1950s, the United States' dominance of the world production of cadmium

Table II. *Trends in the world smelter production of cadmium by decade.*[a]

Country	Cadmium production (metric tons)							
	Total for ten-year periods						Total	
	1910s	1920s	1930s	1940s	1950s	1960s	Country	Continent
North America								197,174
Canada	—	574	2,316	3,792	7,217	9,995	23,894	
Mexico[b]	—	—	5,268	8,334	8,047	7,358	29,007	
U.S.A.	456	3,294	15,241	34,962	42,940	47,380	144,273	
South America								2,002
Peru[b]	—	—	—	22	387	1,593	2,002	
Europe								80,182
Austria	—	—	—	—	44	199	243	
Belgium	—	10	2,270	1,108	5,623	7,839	16,850	
France	—	191	1,216	350	1,401	3,933	7,091	
Germany	521	86	1,860	1,407	2,149	3,896	9,919	
Italy	—	—	418	853	1,844	2,636	5,751	
Netherlands	—	—	—	—	131	697	828	
Norway	—	—	1,204	313	1,014	967	3,498	
Poland	—	—	1,132	1,803	2,340	4,034	9,309	
Spain	—	—	—	10	72	556	638	
United Kingdom[c]	—	29	415	1,460	1,377	1,676	4,957	
Yugoslavia	—	—	—	—	84	718	802	
U.S.S.R.	—	—	115	223	2,290	17,668	20,296	
Africa								17,694
Congo[b]	—	—	—	178	1,979	3,638	5,795	
S.W. Africa[b]	—	—	764	1,537	7,969	1,500	11,770	
Zambia	—	—	—	—	—	129	129	
Asia								18,538
Japan	—	—	206	620	2,921	14,478	18,225	
Korea	—	—	—	—	—	313	313	
Oceania								12,909
Australia	—	1,220	1,895	2,171	3,094	4,529	12,909	
Totals[d]	977	5,404	34,320	59,143	92,923	135,732	—	328,499
Estimated total world production[e]	977	5,404	28,288	49,094	74,999	124,207	—	282,969

[a] Estimates derived from the *U.S. Bureau of Mines* "Minerals Yearbooks" (1932–1969) and CHIZHIKOV (1966).
[b] Includes flue dust and zinc concentrates exported for treatment elsewhere.
[c] Includes secondary production of cadmium.
[d] Totals duplicate cadmium production in those countries where raw materials are mined and exported for processing elsewhere.
[e] Totals by country adjusted to avoid duplication of flue dust and zinc concentrates mined in Mexico and Africa and exported for processing elsewhere.

gradually diminished, due in a large measure to notable increases in its production in Japan and the Soviet Union (Table II). In 1969, the United States produced approximately 34 percent of the world's supply, while Japan and the Soviet Union produced approximately 16 and 14 percent, respectively (MOULDS 1971). During the 1960s very marked increases in cadmium production occurred in Japan and the Soviet Union. About 80 percent of the total produced in these countries has been produced in the past decade.

Production of cadmium in the United States is not solely from raw materials mined here. Over the years the United States has processed imported cadmium-containing flue dust and zinc concentrates from other nations, principallly Mexico, Peru, Canada, Spain, and Australia. Practically all of the total Mexican cadmium production, which has been principally in the form of flue dusts, has been processed in the United States. Disregarding a small amount of cadmium metal produced in Mexico during the 1960s, the data in Table II show that since 1930 about 19 percent of the total United States production was derived from flue dusts imported from Mexico. The United States also imports cadmium metal and the principal suppliers in 1968 and 1969 were Canada, Australia, Peru, and Japan (MOULDS 1971). In 1968 about 38 percent of the primary cadmium produced in the United States was derived from domestic sources, with the remaining 62 percent being imported in the forms of zinc concentrates, flue dust, and metal (DAVIS and ASSOCIATES 1970).

Since cadmium is produced principally from zinc ores, it is expected that increased cadmium production would more or less parallel increased zinc production. Figure 1 shows world cadmium smelter production in terms of percent of world zince smelter production for the period from 1930 to 1969. The individual points in Figure 1 have been obtained from data published in the *U.S. Bureau of*

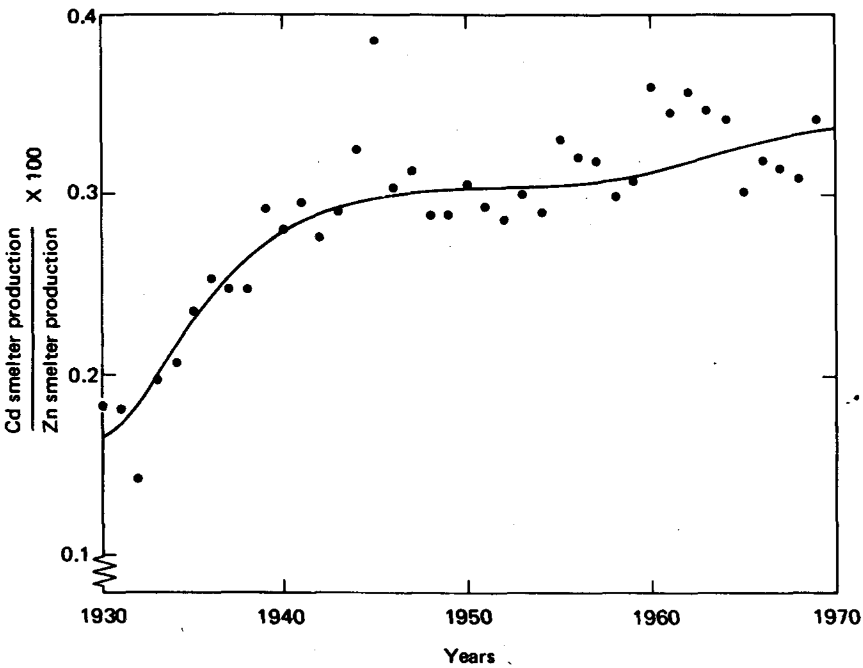

Fig. 1. World cadmium smelter production relative to world zinc smelter production.

Mines "Minerals Yearbooks," 1932–1969. Although there is some scatter of points, which is probably due to faulty production estimates, use of cadmium and zinc stocks, and production of secondary zinc and cadmium, the data show that cadmium production relative to that of zinc increased rather dramatically from 1930 to about 1945. Since 1945 cadmium production has ranged between about 0.3 and 0.35 percent of that of zinc. The rather marked increase in the production of cadmium relative to that of zinc between 1930 and 1945 is the result of improved techniques for the extraction of cadmium from zinc ores. Data presented by LANSCHE (1958 a) show cadmium smelter production for the United States for the years 1946–1955 ranged between 0.31 and 0.48 percent of zinc production with a mean for the period of 0.39 percent. MOULDS (1971) presents figures for cadmium production relative to zinc production which correspond to those presented in Figure 1.

Amounts of cadmium consumed in the United States for ten-year periods from the 1930s throughout the 1960s are presented in Table III. The United States, in addition to being the largest producer of

Table III. *Cadmium production and consumption for the United States by decade.*[a]

Decade	Cadmium (metric tons)	
	Produced	Consumed
1930s	15,241	16,182
1940s	34,962	34,966
1950s	42,940	43,968
1960s	47,380	53,820

[a] Derived from the *U.S. Bureau of Mines* "Minerals Yearbooks" (1932–1969).

cadmium, is the largest world consumer. Consumption here since 1930 has amounted to about 53 percent of that produced in the world during the period. Approximately 70 percent of the total world production has occurred within the last 20 years (Table II); of that produced during this period, about 50 percent has been consumed in the United States.

IV. Uses

Cadmium is used in a wide variety of consumer goods, and virtually all households and industries have products which contain some. Until the early 1960s, practically all of the cadmium consumed in the United States was used in electroplating, pigments and chemicals, and alloys. The *U.S. Bureau of Mines* staff periodically conducts surveys to determine the amounts of cadmium consumed according to use (MILLER and WOOTTEN 1941, WOOTEN 1947, LANSCHE 1958 a and b, SCHROEDER and MILLER 1962). The surveys are rather extensive and the results obtained account for approximately 70 percent of estimated consumption obtained from production, import, and export quantities. Consumption according to use as computed from percentages obtained from surveys and total estimated consumption are presented in Table IV. During 1941–1944, use was somewhat influ-

Table IV. *Consumption of cadmium by use for the United States.*[a]

Year	Consumption					
	Electroplating		Pigments and chemicals		Alloys and solders	
	Amount (metric tons)	% of total	Amount (metric tons)	% of total	Amount (metric tons)	% of total
1941–1944[b]	2,636	74	247	6.8	490	14
1955	2,792	58	1,466	30	447	9.2
1956	3,389	59	1,407	24	670	12
1960	3,223	70	972	22	350	7.6
1965	2,388	50	1,548	33	204	4.4
1968	2,724	45	2,270	38	227	3.8

[a] Data from: 1941–1944, 1955, and 1956, LANSCHE (1958 b); 1960, SCHROEDER and MILLER (1962); and 1965 and 1968, *National Research Council* (1969). The amounts consumed in 1955, 1956, and 1960 have been computed by assuming percentages estimates, as obtained from surveys, are representative of the total estimates consumption.
[b] Annual mean values.

enced by wartime needs; consequently, these data may not be representative of "normal" trends in usage. During the 1960s amounts and percentages of cadmium used in alloys and solders showed a declining trend, while uses for pigments and chemicals showed an increasing trend. The trend in pigments and chemicals is attributed to increased uses in the plastics industry. Since 1955 the amounts of cadmium used in electroplating reveal no consistent trends, but the percent of the total consumption appears to be diminishing.

a) Electroplating

Cadmium is coated over iron, steel, copper alloys, aluminum alloys, and to a lesser extent other metals and alloys by electrodeposition, dipping, or hot spraying. Its use in electroplating consumes the highest percentage of the metal, which annually since 1940 has amounted to 45 to 70 percent of consumption in the United States (Table IV). Products coated with cadmium are many and varied (LANSCHE 1958 b). For most uses, coatings only 7.6 μ thick are satisfactory (SNEED and BRASTED 1955). Materials commonly coated with cadmium include nuts, bolts, screws, rivets, nails, washers, and fasteners. Automobile, truck, tank, agricultural implement, and airplane parts are often coated with cadmium. Household appliances such as vacuum cleaners, refrigerators, washing machines, television sets, radios, and stoves, and office machines such as typewriters, adding machines, and calculators also contain parts or materials which are cadmium-coated. Builder's hardware (locks, hinges, fixtures), industrial hardware (chains, hose couplings, valves, hooks, filters, pulleys), and hand tools (wrenches, pliers, screw drivers) are commonly plated with cadmium. Textile machinery, industrial machinery, amusement and vending machines, heating and refrigeration equipment, petroleum industrial equipment, measurement and control equipment (counters, thermostats, pyrometers, gages), electrical equipment, medical, health, and safety equipment, bicycles, toys, telephones, and fire-fighting apparatus contain parts which are cadmium-coated. Steel stampings, castings, and wire products are also cadmium-coated. LANSCHE (1958 b) has reported amounts of cadmium consumed in electroplating according to use for the United States in 1955 and 1956. Fasteners of various types, automotive and aircraft parts, communication and electrical equipment, and hardware comprised 75 percent of the total cadmium consumed in electroplating for the years reported. Consumption in electroplating in the United States by use for 1960 is reported by SCHROEDER and MILLER (1962). Although the data presented are not as detailed as those presented by LANSCHE (1958 b), trends for cadmium uses in electroplating in 1960 are similar to those reported for 1955 and 1956.

b) Pigments and chemicals

Compounds of cadmium are used rather extensively for imparting high quality red, maroon, yellow, and orange colors to such materials as paints, enamels, rubber, glass, ceramic glazes, textiles, artists' colors, leather, printing ink, and plastics. Pigments of cadmium are noted for their stability to heat, light, and moisture, and for their resistance to weathering by both acids and bases. Cadmium sulfide is one of the best known and widely used compounds as a pigment. Depending upon its method of preparation, its colors range from yellow to orange to dark red. Cadmium yellow (CdS) is widely used by artists in oil painting and is available wherever artists' supplies are sold. Complex cadmium salts containing CdS-$BaSO_4$, CdS-$BaSO_4$-ZnS, and CdS-$BaSO_4$-$CdSe$ are referred to as cadmium lithophones and are widely used to provide a range of yellow, orange, and red pigments. The cadmium lithophones contain from about 15 to 27 percent of this metal (GABBY 1950). Cadmium nitrate is used to impart a reddish-yellow luster to porcelain and glassware, and cadmium acetate trihydrate is used to produce irridescent effects on porcelain and pottery.

For the years 1955 through 1959, cadmium used in the production of cadmium sulfide (CdS) in the United States ranged between about 450 and 565 and averaged 510 metric tons/year (SCHROEDER and MILLER 1962) compared to a range of 700 to 1,100 and an average of 934 metric tons/year for the years from 1965 through 1969 (MOULDS 1971). This rather marked change in the production of CdS is a result of increased use in pigments in the plastics industries (*National Research Council* 1969).

Inorganic and organic cadmium compounds are currently widely used as coloring agents and stabilizers in plastic materials. Cadmium compounds are suitable for this use since they are stable at the high molding temperatures used in plastics production, quite resistant to chemical attack, and resist weathering caused by light and heat. The uses of plastics are far too numerous to mention and the number of products made from plastics is increasing daily. The quantity of cadmium used as pigments in plastics in the United States in 1968 was estimated as 818 metric tons and that used as stabilizers for polyvinyl chloride plastics was 909 metric tons (DAVIS and ASSOCIATES 1970). The 1968 total consumption of cadmium in the United States was 6,058 metric tons (MOULDS 1969) so that, according to the reported figures, use by the plastics industry accounted for about 28 percent of the total consumption in 1968.

c) *Alloys*

Cadmium-containing alloys are used in the production of bearings for aircraft and other internal combustion engines, for solders, and for low-melting and brazing alloys. Amounts of cadmium used in alloying were at their maximum during World War II and have diminished somewhat since that time. For the period 1941–1944 in the United States, cadmium used in alloys averaged about 14 percent of the total consumption, compared to about four and eight percent of the total consumption during the 1960s (Table IV). This reduction is due principally to reduced uses in cadmium-based bearings following World War II (DAVIS and ASSOCIATES 1970).

Low-melting alloys of cadmium are used for solder, automatic fire prevention sprinkler systems, fire-detection apparatus, and safety plugs for tanks and cylinders containing compressed gases. Certain alloys of cadmium with tin, bismuth, lead, and indium have melting points below the boiling point of water. The composition and melting points of a number of these alloys are presented in Table V. The

Table V. *Low-melting alloys of cadmium* (WEAST 1969).

Alloy	Composition (wt. %)					Melting point (°C)
	Cadmium	Tin	Bismuth	Lead	Indium	
Quinternary eutectic	8.2	10.65	40.63	22.11	18.1	46.5
Quinternary eutectic	5.3	8.3	44.7	22.6	19.1	47
Wood's metal	12.5	12.5	50.0	25.0	—	70
Lipowit's metal	10.0	13.3	50.0	26.7	—	70
Ternary eutectic	8.2	—	51.6	40.2	—	91.5

alloys with melting points below the boiling point of water can be used to solder tin, lead, iron, zinc, and brass in hot water.

Silver brazing alloys contain silver, cadmium, copper, and zinc and are used quite commonly as contacts in the electrical and electronics industry. Silver solders containing cadmium in amounts ranging between 15 and 23 percent (Table VI) are used to join both

Table VI. *Composition of cadmium-containing silver solders* (WEAST 1969).

AWS-ASTM classification	Composition (wt. %)				
	Silver	Cadmium	Copper	Nickel	Zinc
B Ag-1	44–46	23	14–16	—	14–18
B Ag-1a	49–51	17	14.5	—	14.5
B Ag-2	34–36	17	25	—	19
B Ag-3	49–51	15	14.5	2.5	13.5

ferrous and non-ferrous metals. Silver-cadmium alloys are used in the jewelry industry for casting ornaments.

A recent use of cadmium is in the production of automobile radiators. Several autombile manufacturers used a copper-cadmium radiator with 0.2 percent cadmium in the 1969 models (*National Research Council* 1969). Alloys containing cadmium have also been used in telephone and tramway wires, high-voltage transmission lines, and cable sheating (CHIZHIKOV 1966).

d) Other uses

Cadmium usage in batteries constitutes the largest single use outside of the areas of electroplating, pigments and chemicals, and alloys. The amount used in the United States for the production of batteries in 1968 was 182 metric tons (DAVIS and ASSOCIATES 1970) or about three percent of the total consumption for that year. Growth in the production of products which utilize cadmium-batteries has increased substantially in the past decade, and similar growth is expected to be experienced in the coming decade. Both sealed and vented nickel-cadmium batteries are produced. Convenience appliances and portable communication equipment are the principal kinds of products which utilize sealed cells. Cordless household items such as toothbrushes, electric shavers, flashlights, and knives use these batteries as the power source. Sealed cells are also used in missile systems and in space exploration equipment. Vented cells are used chiefly in aircraft, but have also been used as power sources in buses and diesel locomotives.

Small amounts of cadmium are used in the production of fungicides. Although there are about 12 such fungicides marketed, the amounts used in the United States for this purpose were only about 11 metric tons in 1968 (DAVIS and ASSOCIATES 1970). Other areas where small amounts of cadmium are used include control rods for nuclear reactors, phosphors for television tubes, fluorescent lamps, luminescent dials, compounds in photography, lithography, process engraving, and curing rubber, and various miscellaneous uses.

V. Residues in soil, water, air, vegetation, and foods

a) Soil

The concentrations of cadmium in noncultivated soils not subjected to contamination from sources other than the parent rocks from which the soil has been derived are governed by the quantities of cadmium found in the parent materials. Based upon the cadmium concentrations reported for common rocks (Table I), one would suspect that, on the average, soils derived from igneous rocks would be the lowest in total cadmium, soils derived from metamorphic rocks would be intermediate, and soils derived from sedimentary rocks would contain the largest quantities of total cadmium. The information presented in Table I suggests that soils derived from igneous rocks should contain about 0.1 to 0.3 p.p.m. of cadmium, those derived from metamorphic rocks about 0.1 to 1.0 p.p.m., and those derived from sedimentary rocks 0.3 to 11 p.p.m.

Native vegetation may serve to cause a noticeable distribution of all elements within a soil profile. The vegetation growing on soil