Water Quality Control Board Publication No 3-A

Pb in Water 1455

Adult bluegills exposed up to four weeks in water containing 0.25 mg/l of lactonitrile did not pick up any organoleptic properties that could be detected by a taste panel (2958).

LANTHANUM La

(see also Chapter VIII—Radioactivity)

This rare-earth metal occurs in nature chiefly as the oxide in several minerals, frequently associated with cerium. It is used as a weighting agent for silk and rayon, in the manufacture of glass and ceramics, and in "flint" lighters (364, 2121). The chloride, hydroxide, and nitrate salts are highly soluble in water; but the carbonate, oxide, and sulfate are insoluble. Hence, lanthanum ions in waste waters are likely to be precipitated and removed by sedimentation or adsorption, as carbonates or sulfates.

Lanthanum is not recognized as a toxic element for man or animals. The LD_{50} values for rats, in terms of lanthanum were reported (3526, 3527) as 4440 mg/kg for lanthanum acetate, 1450 mg/kg for the nitrate, 2450 mg/kg for the sulfate, and over 8500 mg/kg for the oxide.

Using water from the River Havel from which the test organisms were recovered, Bringmann and Kuhn (2158, 3343) studied the threshold effects of lanthanum acetate on four organisms. For *Daphnia* exposed for 48 hours at 23°C, the median threshold effect occurred at 160 mg/l, expressed as lanthanum. For *Scenedesmus* exposed for 4 days at 24°C, the median limit was only 0.15 mg/l of lanthanum; for *E. coli* at 27°C it was 0.4 mg/l, and for a protozoan (*Microregma*) it was 24 mg/l.

LARVICIDES

(see Chapter IX)

LAURYL DIMETHYL BENZYL AMMONIUM CHLORIDE

(see Chapter X)

LEAD Pb

1. General. Some natural waters contain lead in solution, as much as 0.4-0.8 mg/l, where mountain limestone and galena are found. In the U.S.A., lead concentrations in surface and ground waters used for domestic supplies range from traces to 0.04 mg/l averaging about 0.01 mg/l (3528). Lead may also be introduced into water as a constituent of various industrial and mining effluents, or as a result of the action of the water on lead in pipes.

In the examination of waters for various beneficial uses, their action on lead may be of great importance and should always be considered since lead is frequently used for service and domestic pipes and water-storage chambers. The factors that determine the action of plumbo-solvent waters are complex and not yet fully understood. Practically all waters have a slight action on new lead pipes, although in most cases it is only transient and insufficient to be harmful. Normally the internal lead surfaces quickly acquire a protective coating, after which no further lead is dissolved by the water. With certain types of water, however, no such protective covering is developed, or its formation may be so slow that the solution of lead can go on for a long time. The characteristics of water, soft or hard, that appear to be conducive to plumbo-solvency include comparative absence of calcium and magnesium bicarbonates, low pH, high dissolved oxygen, and high nitrate content (36, 1199, 1226).

The following material was gathered from references in which the effects of lead were given without details of the entire compound, if any. Where specific lead salts were mentioned, the data were listed under the appropriate salt. Certain lead salts, such as the acetate and chloride, are readily soluble, but owing to the fact that the carbonate and hydroxide are insoluble and the sulfate is only sparingly soluble, lead will not remain long in natural waters.

2. Cross References. Dissolved Oxygen, pH, Lead Acetate, Lead Arsenate, Lead Chloride, Lead Fluoride, Lead Nitrate, Lead Sulfate, Tetraethyl Lead.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. Foreign to the human body, lead is a cumulative poison. It tends to be deposited in bone as a cumulative poison. The intake that can be regarded as safe for everyone cannot be stated definitely, because the sensitivity of individuals to lead differs considerably. Typical symptoms of advanced lead poisoning are constipation, loss of appetite, anemia, abdominal pain, and tenderness, pain, and gradual paralysis in the muscles, especially of the arms. A milder and often undiagnosed form of lead poisoning also occurs in which the only symptoms may be lethargy, moroseness, constipation, flatulence, and occasional abdominal pains (36). Lead poisoning usually results from the cumulative toxic effects of lead after continuous consumption over a long period of time, rather than from occasional small doses. Immunity to lead cannot be acquired, but sensitivity to lead seems to increase (1227). Lead is not among the metals considered essential to the nutrition of animals or human beings (2121).

Lead may enter the body through food, air, and tobacco smoke as well as from water and other beverages. Consequently, the total intake of lead must be considered in setting standards for water. The exact level at which the intake of lead by the human body will exceed the amount excreted has not been established, but it probably lies between 0.3 and 1.0 mg per day (152). The mean daily intake of lead by adults in North America is about 0.33 mg. Of this quantity, 0.01 to 0.03 mg per day are derived from water used for cooking and drinking (3528, 3529). A total intake of lead appreciably in excess of 0.6 mg per day may result in the accumulation of a dangerous quantity of lead during a lifetime. Lead in an amount of 0.1 mg ingested daily over a period of years has been reported to cause lead poisoning (1228, 1229). The daily ingestion of 0.2 mg lead is considered excessive by one authority (1230). On the other hand one reference considered 0.5 mg per day safe for human beings, and a daily dose of 2.0 mg for a one-year period apparently did not affect the health of one adult (353).

Lead poisoning among human beings is reported to have been caused by the drinking of water containing

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lead in concentrations varying from 0.042 mg/l to 1.0 mg/l or more (27, 29, 32, 36, 620, 997, 1231, 1232, 1233, 1234, 1235, 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1243, 1244, 1245, 2326, 3530, 3531). On the other hand, concentrations of 0.01 to 0.16 mg/l have been apparently non-poisonous over long periods of time (1077, 1201, 3532). However, there is a feeling that 0.1 mg/l may cause chronic poisoning if the water is used continuously, especially among hypersensitive persons (29).

For many years, the mandatory limit for lead in the USPHS Drinking Water Standards was 0.1 mg/l; but in the 1962 Standards, the limit for lead was lowered to 0.05 mg/l. In the WHO International Standard and WHO European Standards (see Chapter V) the limit for lead has been set at 0.1 mg/l. In the past, the Netherlands and Germany have permitted a temporary lead concentration up to 0.3 mg/l in water that had been in pipes for 24 hours (997, 1229, 3530). Uruguay, on the other hand, has used a standard as low as 0.02 mg/l (1457). Several countries use 0.1 mg/l as a standard.

Owing to the fact that the total intake of lead from food, inhaled atmosphere, and tobacco smoke in industrial urban areas appears to be increasing, with little chance of regulation and diminution, and inasmuch as the concentration of lead in drinking water can be controlled without undue hardship on water purveyors, the USPHS Drinking Water Standard for lead was lowered to 0.05 mg/l in 1962 (2062, 2672). It is significant, however, to note that the U.S. Government has also established a tolerance of lead in food at 7 mg/kg, more than 100 times the limit for drinking water (3533).

b. Industrial Water Supplies. Traces of lead in metal-plating baths will affect the smoothness and brightness of deposits (214).

c. Irrigation. Inorganic lead salts in irrigation water may be toxic to plants and should be investigated further (269, 1014). Klintworth (1493) stated that lead is harmful to plants at all concentrations. On the other hand, the addition of 2.0 mg of lead per kg of dry soil in pot tests increased the nitrogen content of peas (2926). In the culture of oats and potatoes, lead nitrate in concentrations of 1.5 to 25 mg/l had a stimulating effect, but at concentrations over 50 mg/l all plants died in a week's time (2997). See also lead salts.

Lead at a concentration of 51.8 mg/l of nutrient solution was slightly injurious to sugar beets grown in sand culture (1473). Germination of cress and mustard seeds in solution culture was completely inhibited by a 2760 mg/l lead solution, during an exposure period of 18 days. Germination was delayed and growth was retarded by 345-1380 mg/l of lead (1479).

d. Stock and Wildlife Watering. Farm animals are poisoned by lead from various sources, including paint, more frequently than by any other metallic poison (1247). It is not unusual for cattle to be poisoned by lead in the water; the lead need not necessarily be in solution, but may be in suspension, as, for example, oxycarbonate (36). Chronic lead poisoning among animals has been caused by 0.18 mg/l of lead in soft water (1232); and by concentrations under 2.4 mg/l (1238). Chronic changes in the central nervous system of white rats were observed after an ingestion of 0.005 mg of lead per kg of body weight (3534). Most authorities agree that 0.5 mg/l of lead is the maximum safe limit for lead in a potable supply for animals (1238).

Allcroft (1589) reported that calves given as much as 2.0 grams of lead daily have survived for 2 to 3 years. Calves have tolerated daily doses of 8 mg and 6 mg of lead per kg of body weight for, respectively, many months and up to three years. Doses of 0.2-0.4 grams of lead per kg body weight caused death within a few days (1590). When a calf was given drinking water containing lead nitrate at a concentration of 100 mg/l of lead, it survived for only four months. It was suggested that nitrate was partly responsible for the death (1589). Geese have been reported to have contracted lead poisoning from the ingestion of mine tailings (3535).

e. Fish and Other Aquatic Life. The toxic concentration of lead for aerobic bacteria is reported to be 1.0 mg/l; for flagellates and infusoria, 0.5 mg/l. The bacterial decomposition of organic matter is inhibited by 0.1 to 0.5 mg/l of lead (576, 2977, 3324, 3534).

Carpenter and others have studied the effects of small concentrations of heavy metals, particularly lead, upon fish. Such studies indicate that in water containing lead salts, a film of coagulated mucus forms, first over the gills, and then over the whole body of the fish, probably as a result of a reaction between lead and an organic constituent of mucus. The death of the fish is caused by suffocation due to this obstructive layer (346, 991, 1248, 2411). In soft water, lead may be very toxic; in hard water equivalent concentrations of lead are less toxic (311). Calcium in a concentration of 50 mg/l has destroyed the toxic effect of 1.0 mg/l of lead (353).

Wilder found that lobsters died within 20 days when kept in lead-lined tanks; however, in steel-lined and other control tanks they survived for 60 days or longer (1530). Small sticklebacks appeared to be slightly more sensitive to lead than the larger fish (1460).

The Water Pollution Research Board (74) in England conducted extensive experiments to determine the effects of lead salts on rainbow trout in hard and soft waters. In water of the lowest hardness used, 14 mg/l as $CaCO_3$, all of the lead added as lead nitrate remained in solution and produced a curvilinear relationship of lead concentration vs time of survival. A similar curve was obtained for a water with a total hardness of 27 mg/l as $CaCO_3$, although some precipitation of $PbCO_3$ occurred with lead concentrations greater than 8.0 mg/l. In solutions with a total hardness of 53 mg/l as $CaCO_3$ the maximum concentration of lead remaining in solution was approximately 1.6 mg/l, and the median period of survival of the trout exceeded two days even at lead dosages in excess of 20 mg/l. It seems probable, therefore, that precipitated lead carbonate is not effective as a lethal agent. For further evidence that insoluble lead is not highly toxic to fish, see Lead Oxide.

A chart submitted by the Water Pollution Research Board (74) indicates that the median period of survival of rainbow trout in soft water containing dissolved lead, at 18.5°C, was 18 to 24 hours at 1.6 mg/l and only 10 to 12 hours at 4.0 mg/l.

The Water Pollution Research Board has also shown that the toxicity of lead toward rainbow trout increases with a reduction of the dissolved-oxygen concentration of the water (74, 88, 3321, 3322). The following table shows factors by which the threshold concentration of lead must be multiplied to determine concentrations of equal toxicity at lower dissolved-oxygen tensions:

Dissolved oxygen (percent of saturation)	100	80	60	40
Factor	1.0	0.95	0.85	0.71

The following concentrations of lead have been reported toxic or lethal to fish in the time specified (see also the various lead salts):

Concentration of lead, in mg/l	Type of water	Time of exposure	Species of fish	Reference
0.1	--	--	Fish	353, 573, 1249
0.1	--	--	Sticklebacks	1460, 2920, 2941
0.1-0.2	very soft	--	Sticklebacks	1459
0.2	soft	--	Fish	3319
0.21	--	--	Guppy	2921
0.25	fresh	--	Fish	598
0.33	--	--	Minnows, brown trout and sticklebacks	311, 313, 353, 2920
0.34	1000-3000 mg/l of dissolved solids	48-hour TL_m	Sticklebacks and coho salmon	3536
0.4	distilled	26-48 hours	Minnows	1459
0.41	1000-3000 mg/l of dissolved solids	24-hour TL_m	Coho salmon	3536
0.53	1000-3000 mg/l of dissolved solids	24-hour TL_m	Sticklebacks	3536
0.75	--	--	Minnows	353
1.0	--	long-term	Carp	3327
1.0	--	8.5 days	Sticklebacks	1444, 1460
1.4	soft	18-24 hours	Rainbow trout	74
1.4	tap	48-hour TL_m	Bluegill sunfish	2093
2.0	tap	24-hour TL_m	Bluegill sunfish	2093
2.4E	soft	96-hour TL_m	Fathead minnows	2154, 2125
2.7	distilled	4-16 hours	Minnows	313
2.8	fresh	--	Fish	2931
4.0	soft	10-12 hours	Rainbow trout	74
4.0	--	--	Fish	313
5.5	stream water	--	Trout	313, 598, 609
5.5	distilled	--	Goldfish	313
6.3	tap	24 & 48-hour TL_m	Bluegill sunfish	2093
10.0	--	--	Goldfish	1459, 2920
17	--	--	Goldfish	1459
27	tap	16-183 days	Catfish	1459
40	--	80 hours	Goldfish	1466
63	--	80 hours	Goldfish	1466
75E	hard	96-hour TL_m	Fathead minnows	2154, 2125

E = exploratory test only

The following concentrations of lead have not visibly harmed fish within the time specified:

Concentration of lead, in mg/l	Type of water	Time of exposure	Species of fish	Reference
0.62	--	48 hours	Trout	1459
0.7	soft tap water	3 weeks	Minnows and Sticklebacks	1459
1.0	very soft	indefinitely	Col fish	1459
4.0	--	--	Plaice eggs	1459

Toward the giant kelp, *Macrocystis pyrifera*, North and Clendenning (2107) found that lead was less toxic than mercury, copper, hexavalent chromium, zinc, and nickel. Lead nitrate produced no deleterious effect on the rate of photosynthesis of kelp in sea water during a four-day exposure at 4.1 mg/l of lead.

The Mersey and Severn River Boards in England have established "working standards" for several streams whereby the total concentration of all heavy metals, including lead, cannot exceed 1.0 mg/l.

4. Summary. In view of the 1962 Drinking Water Standards of the USPHS, setting a mandatory limit of 0.05 mg/l on lead in water delivered to the consumer, and in light of the fact that lead concentrations as low as 0.1 mg/l have been deleterious to fishlife, especially in soft waters, it is evident that the dissolved lead content of surface waters should be restricted to 0.1 mg/l where these two beneficial uses are involved.

LEAD ACETATE $Pb(C_2H_3O_2)_2 \cdot 3H_2O$

1. General. Known also as "sugar of lead", this freely soluble lead salt is used in printing and dyeing operations, in the weighting of silk, and in the manufacture of other lead salts.

2. Cross References. Acetate, Lead, and other lead salts.

3. Effects Upon Beneficial Uses.

a. Irrigation. When lead acetate was tested, 1000 to 10,000 mg/l of lead severely stunted the growth of water hyacinths in water culture; and 1 to 100 mg/l retarded growth (1525). In nutrient solution containing lead acetate, 1500 to 20,000 mg/l of lead inhibited the germination of cress and mustard seeds; however, even after 18 days of exposure to lead, the seeds germinated when they were transferred to water cultures (1479).

b. Fish and Other Aquatic Life. Dawson (1459) found evidence of injury to blood cells of catfish exposed for 16 to 183 days to a 50 mg/l solution of lead acetate (27 mg/l of Pb) in tap water, renewed at 48-hour intervals. Minnows were killed in 26 to 48 hours by 0.4 mg/l of lead in a solution of lead acetate in non-toxic distilled water, renewed at regular intervals during the observation period.

It has been reported that lead acetate concentrations of 10 mg/l in stream water killed trout (313, 598, 609). In distilled water, 5.0 mg/l of lead acetate killed minnows in 4 to 16 hours; and 10 mg/l in distilled water renewed every second day, killed goldfish in 12 days (313). The Washington Department of Fisheries (2931) reported that lead acetate at a concentration of 2.8 mg/l of lead killed fish in fresh water; but Fujiya (3327) maintained that long-term exposure of carp to a much lower concentration of lead acetate (1.0 mg/l as Pb) resulted in a harmful effect to their serum.

LEAD ARSENATE $PbHAsO_4$

1. General. Lead arsenate sprays are used for insect control on crop lands, especially for the gypsy moth and boll weevil; but it is believed that such use has not resulted in the contamination of water supplies derived from treated watershed areas (152). Fortunately, lead arsenate is highly insoluble in water.

2. Cross References. See Lead, Arsenic, other arsenic compounds.

3. Effects on Beneficial Uses.

a. Domestic Water Supplies. Lead arsenate is more toxic to humans than lead carbonate. A total of 100 mg of lead arsenate ingested by two individuals over a period of 10 days caused no apparent harm (353).

b. Stock and Wildlife Watering. In doses of 1.3 to 56.7 grams per day, lead arsenate killed 13 out of 31 chickens, but the survivors showed no symptoms of poisoning. Drinking water containing about 1800 mg/l of lead arsenate caused no harm to 10 birds after a 60-day

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period (1013). Toward male rats, the LD_{50} value of lead arsenate has been reported as 1050 mg/kg. The daily consumption by one cow of 6.48 grams of lead arsenate for an unspecified period was not harmful (1014).

c. Fish and Other Aquatic Life. A concentration of 25 mg/l of lead arsenate has killed trout within 24 hours (359), but a concentration of 17.1 mg/l in stabilized tap water did not harm minnows during a one-hour exposure(362).

LEAD CHLORIDE $PbCl_2$

(see also Chlorides, Lead and other lead salts)

This relatively soluble lead salt is used in the manufacture of certain lead paints and as a solder and flux. The following concentrations of lead chloride have been reported as deleterious toward aquatic life:

Concentration of Lead Chloride, mg/l	Type of water	Time of exposure	Type of organism	Reference
0.01 to 1.0	many kinds	10 days	*Daphnia magna*	598
0.33	--	--	fresh-water fish	598
0.58	Lake Erie	--	whitefish fry	2955
1.25	Lake Erie	--	*Daphnia magna*	2955
3.2E	soft	96-hr. TL_m	Fathead minnows	2154, 2125
10.0	distilled	24 hours	*Daphnia magna*	654
>100E	hard	96-hr. TL_m	Fathead minnows	2154, 2125
128	Lake Erie	--	*Cyclops vernalis*	2955

E = exploratory test only

It was also reported (654) that *Daphnia magna* withstood 10 mg/l of lead chloride for 5 hours, but succumbed in 24 hours.

LEAD OXIDE PbO

This insoluble white powder is used extensively in paints. Wallen et al. (2940) tested its toxicity toward the mosquito fish (*Gambusia affinis*) in water having a turbidity from soil suspension of 315 mg/l, a pH range of 7.1 to 7.2, and a temperature range of 18 to 20°C. He found that the 96-hour TL_m was greater than 56,000 mg/l and there was no significant decrease in turbidity as a result of the addition of lead oxide. Apparently insoluble lead is not toxic to fish.

LEAD NITRATE $Pb(NO_3)_2$

(see also Lead, Nitrates)

Used in the manufacture of matches and special explosives, as a mordant in dyeing and printing of textiles, as an oxydizer in the dye industry, and in photography and engraving, this lead salt is highly soluble in water (364).

For tadpoles in tap water, 1.6 mg/l of lead nitrate is deleterious to growth and 3.3 mg/l is lethal (313). Fish appeared to try to avoid, i.e., react negatively, to solutions of lead nitrate varying in strength from 0.33 to 644 mg/l, but reacted positively to a 6640 mg/l solution after a temporary initial negative reaction (1046).

Westfall found that concentration of dissolved oxygen has a significant effect on the response of goldfish to lead nitrate, for example, all the fish tested survived a 2-hour exposure to 5 mg/l of lead nitrate in the presence of 6.2 mg/l of oxygen, but all the fish tested died within 2 hours in the presence of only 1.4 mg/l of dissolved oxygen (1459).

In fresh water, 3 mg/l lead nitrate has been fatal to *Fundulus* within 12 hours (1459). Using lead nitrate, Jones found the lethal concentration limit of lead for sticklebacks to be 0.1 mg/l. At different concentrations of lead, the average survival times of the fish were as follows: one day at 1.0 mg/l, two days at 0.7 mg/l, four days at 0.3 mg/l, and one week at 0.2 mg/l (1460). However, goldfish died only after an 80-hour exposure to 63 mg/l of lead (1466). Minnows died within 48 hours when exposed to 0.4 mg/l of lead in a solution of lead nitrate in non-toxic distilled water (1459).

The following concentrations of lead nitrate have been reported to have killed fish:

Concentration of Lead Nitrate, in mg/l	*Type of water*	*Time of Exposure*	*Type of Fish*	*Reference*
0.16	tap	--	stickleback	2920, 598
0.53	tap	--	minnows, sticklebacks, and brown trout	2920
10	natural	2.5 hours	trout	313, 598
10	tap	24 and 48-hr TL_m	bluegill sunfish	2093
10	hard	4 days	goldfish	353
16	tap	--	goldfish	2920
16.6	--	20 hours	minnows	353
100	hard	80 hours	goldfish	313
165	distilled	--	fish	313
240	highly turbid	96-hr TL_m	mosquito-fish	2940
250	distilled	4-5 days	goldfish	313
250	distilled	2-3 hours	minnows	313
830	--	3 hours	minnows	991
3320	--	2.2 hours	minnows	991
8300	--	1.5 hours	minnows	991
16600	--	1.4 hours	minnows	991, 1243
44000	--	44 minutes	minnows	1243
53000	--	40 minutes	minnows	1243

On the other hand, 10 mg/l of lead nitrate in hard water has not harmed fish during a 96-hour exposure period (313).

Bringmann and Kuhn (2158, 3343) tested the effects of lead nitrate in River Havel water at pH 7.5 and a temperature of 24°C against several organisms during an exposure of 4 days. The threshold concentrations for deleterious action were as follows:

Test Organism	*Threshold Concentration in mg/l of Lead*
Daphnia magna	5.0
Scenedesmus	2.5
Escherichia coli	1.3
Microregma	1.25

Cleland (3328) found that lead nitrate in a concentration of about 200 mg/l in sea water produced abnormalities in the eggs of sea urchins.

LEAD SULFATE $PbSO_4$

(see also Lead, Sulfates)

Sparingly soluble in water, this salt is used as a paint pigment, for weighting fabrics, in lithography, and in galvanic batteries. In distilled water 25 mg/l of lead sulfate killed goldfish in 4 days and killed minnows in 2 to 3 hours (313). Jones (2920) reports the lethal concentration for goldfish as 26 mg/l.

LEAD TETRAETHYL $Pb(C_2H_5)_4$

Used as an additive in motor fuels to prevent knocking, this lead compound might occur in the effluents from refineries. Turnbull et al. (2093) conducted bioassays with this substance in Philadelphia tapwater, using bluegill sunfish (*Lepomis macrochirus*) as the test fish. They found a 24-hour TL_m of 2.0 mg/l as lead and a 48-hour TL_m of 1.4 mg/l. They estimated the safe concentration at 0.20 mg/l.

LIGNASAN

(see Mercuro-Organic Compounds)

LINOLEIC ACID AND LINOLEATES

(see Fatty Acids)

LISSAPOL (NONYLPHENOL ETHYLENE OXIDE CONDENSATE)

(see Chapter X)

LIME

(see Calcium Hydroxide)

LINDANE

(see Chapter IX—Benzene Hexachloride)

LITHIUM Li

(see also Lithium Chloride)

As one of the alkali metals, related to sodium and potassium, lithium is not widely distributed in nature, being found in a few minerals and in certain spring waters. Being very active, the metal does not occur in the elemental state and when purified as such it must be protected from water or oxygen. It is used in metallurgy, in medicinal waters, in some types of glass, and as lithium hydroxide in storage batteries. Hibbard (250) recommends, without references, that lithium in water for drinking and cooking purposes should not exceed 5 mg/l.

Lithium toxicity in citrus has been identified in Santa Barbara County, California. In green-house experiments, 2 and 5 mg/l of lithium sulfate (in air-dried soil) caused the appearance of toxic symptoms in orange seedlings within 6 months. In the field, 1, 2, and 4 mg/l of lithium chloride in the soil have caused symptoms of lithium toxicity.

Various irrigation waters in the area were found to contain 0.045-0.080 mg/l of lithium. Possibly lithium poisoning has resulted from the accumulation in ground of toxic concentrations over a long period of time. Aldrich (1591) and his collaborators are making further studies of the effects of 0.05-0.1 mg/l of lithium in irrigation water.

LITHIUM CARBONATE Li_2CO_3

This light white alkaline powder, quite soluble in water, is used in the production of glazes on ceramic and electrical porcelain (364). It was reported in 1923 that concentrations of 295-516 mg/l of lithium carbonate retarded larval and pupal development of *Drosophila melanogaster* (1592).

LITHIUM CHLORIDE LiCl

(see also Lithium)

A white deliquescent crystalline solid, lithium chloride is highly soluble in water. It is used in pyrotechnics and in the soldering of aluminum. It is also used in the manufacture of mineral waters and it may be found in some natural mineral springs (364).

In a concentration of 3750 mg/l, lithium chloride in distilled water killed goldfish in 22 to 27 hours (313). For mature small fresh-water fish, the lethal concentration in 24 hours of exposure was found to be 2600 mg/l. The data gathered by Powers and by Iwao indicate that lithium chloride at concentrations between 1950 and 3770 mg/l can kill fresh-water fish in about one day, or sooner at warmer temperatures (1459). In contrast with these high concentrations required for lethal effect, one German publication (2977) reports that 100 mg/l of LiCl is toxic but 33 mg/l is harmless to fish.

The threshold concentration for immobilization of *Daphnia magna* in Lake Erie water was found to be less than 7.2 mg/l (598); but in River Havel water at 23°C the threshold of poisonous effect was observed at 16 mg/l during 48 hours contact (2158). With the protozoan *Microregma* as the test organism, food intake was inhibited at 66 mg/l (3343). Toward *Scenedesmus* and *Escherichia coli*, no toxicity was evident at concentrations less than 1000 mg/l (2158). In order to evoke stimulation and movement of the water beetle, *Laccophilus maculosis*, a LiCl concentration of 19,500 mg/l was required (2956).

It has been reported that dilute concentrations of LiCl are deleterious to the eggs of various aquatic organisms, retarding their development and producing monstrosities (1467). King demonstrated that concentrations of 848 mg/l were highly toxic to fly larvae, preventing emergence of offspring and retarding development of both larvae and pupae (1592).

LITHIUM FLUORIDE LiF

This moderately soluble salt is used as a flux for soldering and welding aluminum and in the manufacture of vitreous enamels and glazes (364). The oral LD_{50} for guinea pigs is 200 mg/kg of body weight (3271). The lethal dose in 48 hours for the fish, *Tinca vulgaris*, is reported as 20,000 mg/l (3271).

LITHIUM SULFATE

(see Lithium)

LOROL METASODIUM SULFOBENZOATE

(see Chapter X)

MAGNESIUM Mg

1. General. As one of the most common elements in the crust of the earth, constituting about 2.1 percent of it, magnesium is widely distributed in ores and minerals (364). Because it is very active chemically, it is not found in the elemental state in nature. With the exception of the hydroxide at high pH values, its salts are very soluble; even the carbonate will dissolve to the extent of 100 to 300 mg/l at normal temperatures (364, 911). The solubility of magnesium hydroxide is governed by the equation:

$$[Mg^{++}]\ [OH^-]^2 = 1.2 \times 10^{-11} \text{ at } 18°C$$

Thus, at pH 7, magnesium ions theoretically can be present to the extent of 1200 mols per liter or 28,800