Radioactivity In The Ohio River

Introduction

Traces of naturally-occurring radioactivity can be found in almost all living and non-living substances. Cosmic rays bombard our atmosphere from outer space; radioactive elements and compounds in rocks decay; radium and tritium dials on wristwatches glow in the dark; and x-rays and radioisotopes are used extensively for medical and dental purposes. Radiation can also be found in the air and water around us and in common materials such as wood and brick. All of these are forms of radioactivity.

This report concerns radiation levels in the Ohio River. The Ohio River is the source of drinking water supply to more than three million people. As such, its waters are extensively monitored for a wide range of contaminants, including heavy metals, nutrients (nitrogen and phosphorus compounds), organic chemicals (especially volatiles like chloroform and carbon tetrachloride) and radioactivity.

Sources of Radioactivity

Historically, the concern about radioactivity in the Ohio River was with man-made sources, the result of open-air testing of nuclear weapons in the late 1940's, 1950's, and early 1960's. These tests released large amounts of radioactivity to the atmosphere, which then found their way into water and soil, and eventually into the food chain. The US Public Health Service initiated a national water monitoring program for radioactivity in 1957. In 1963, a test ban treaty ended most open-air nuclear test explosions.

Since 1963, radioactivity levels have declined markedly. This has occurred despite the growth in the use of radioactive materials in electrical power generation through nuclear energy, medicine and research and other industrial applications. In the Ohio Valley, there are two nuclear power plants, both in the upper river between Pittsburgh, PA, and Wheeling, WV: the Shippingport Atomic Power Station (currently inoperative

The Ohio River Valley Water Sanitation Commission is an interstate agency formed in 1948 to control water pollution in the Ohio Valley. Member states are: Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia and West Virginia. The federal government is also represented on the Commission.

and to be decommissioned in 1984) and the Beaver Valley Power Station. The generating capacity of these plants amounts to about 2.5 percent of the total generating capacity of all power plants on the Ohio River. Two nuclear power plants are under construction in the middle Ohio River area: William H. Zimmer Nuclear Station near Cincinnati, OH, and Marble Hill Nuclear Station near Madison, IN. A second unit at Beaver Valley is also under construction (see map, Figure 1).

At various times between the mid-1960's and the present, the states of Indiana, Illinois, Ohio, Kentucky, Pennsylvania and West Virginia have monitored radioactivity in the parts of the Ohio River that form their borders. The Ohio River Valley Water Sanitation Commission (ORSANCO), US Geological Survey (USGS) and US Environmental Protection Agency (US EPA) have monitored the entire river at selected sites during this period, as well.

Levels of Radioactivity in the Ohio River

For purposes of this report, six locations were selected to present a profile of radioactivity from beta particles (see Figure 3 for explanation of radioactive particles) in the Ohio River. The data base for gross beta radiation is more extensive than that of other radioactive particles because beta was considered a good indicator of radiation levels resulting from nuclear fallout. Data are available for 75 locations on the river, but many of these were sampled for only a few years. In some cases, sampling points close to one another have been grouped to form the six stations profiled (see Figure 2).

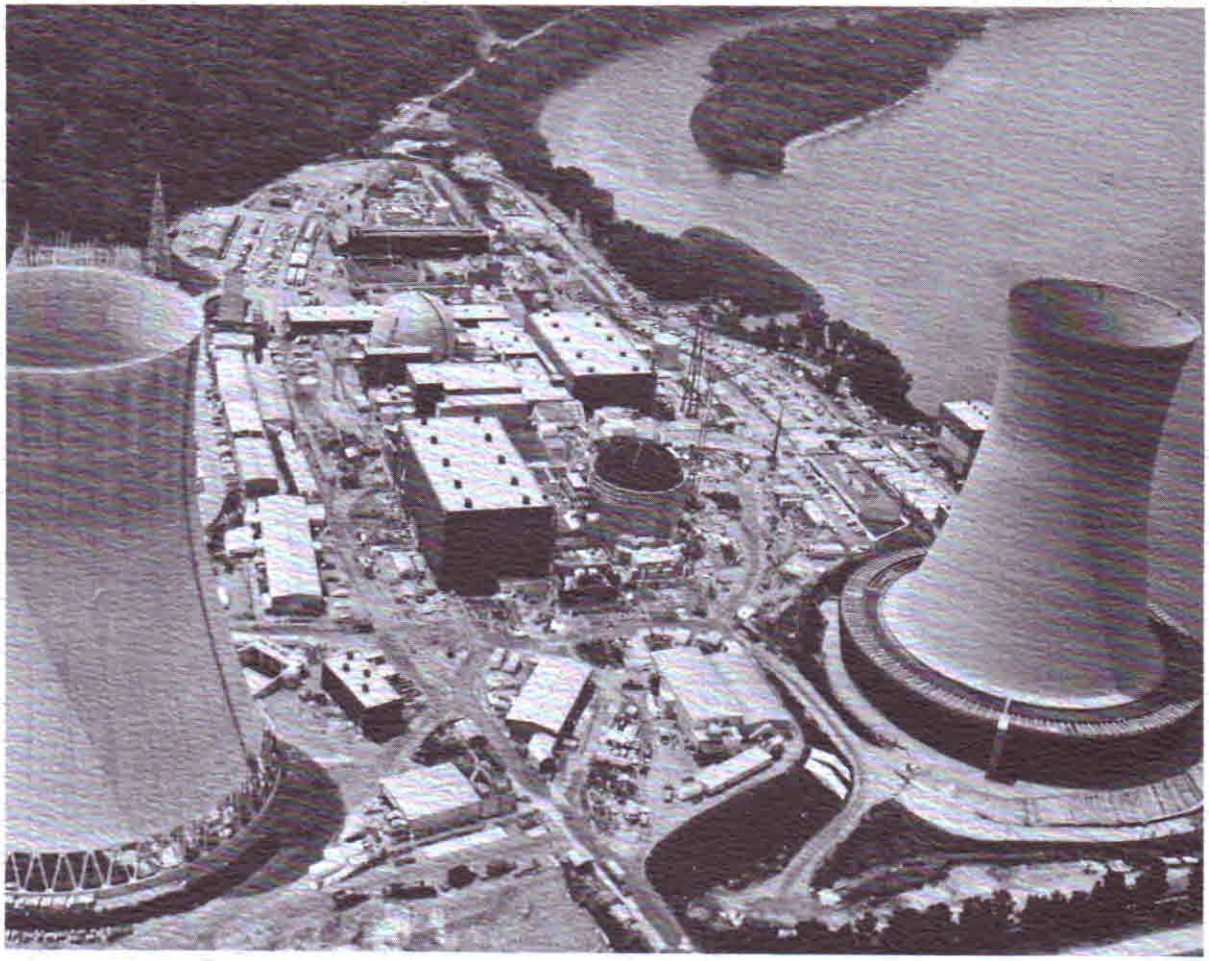
Data from US Public Health Service monitoring in 1960, 1961 and the first part of 1962 indicate that most beta activity then was in the form of natural background radiation. Average levels in the Ohio River were similar to average levels throughout the United States — between 5 and 20 picocuries per liter (pCi / l;see Figure 4 on measurement of radioactivity).

However, radioactivity sampling undertaken in the early 1960's by the University of Louisville's Potamological Institute under contract to the Commission showed beta levels in 1962 as high as 90 pCi / l and 177 pCi / l at the Markland Dam and the mouth of the Great Miami River, respectively. US Public Health Service data show that in the second half of 1962 and in 1963, average levels in the Ohio River rose to between 29 and 83 pCi / l with the average level at most of the six sites profiled here above the current standard of 50 pCi / l (see radioactivity criteria, Figure 5). The highest values recorded by the US Public Health Service in the Ohio Valley were 421 pCi / l in 1962 at Evansville, IN, and 771 pCi / l in 1963 at Cairo, IL.

Since the test ban treaty of 1963, levels of beta radiation have decreased substantially. At times, average levels at certain locations have been below detection limits. The maximum one-time level of beta recorded since 1963 was 54 pCi / l in the Louisville, KY-New

Beaver Valley Nuclear Power Station

Photo courtesy of Ohio Edison



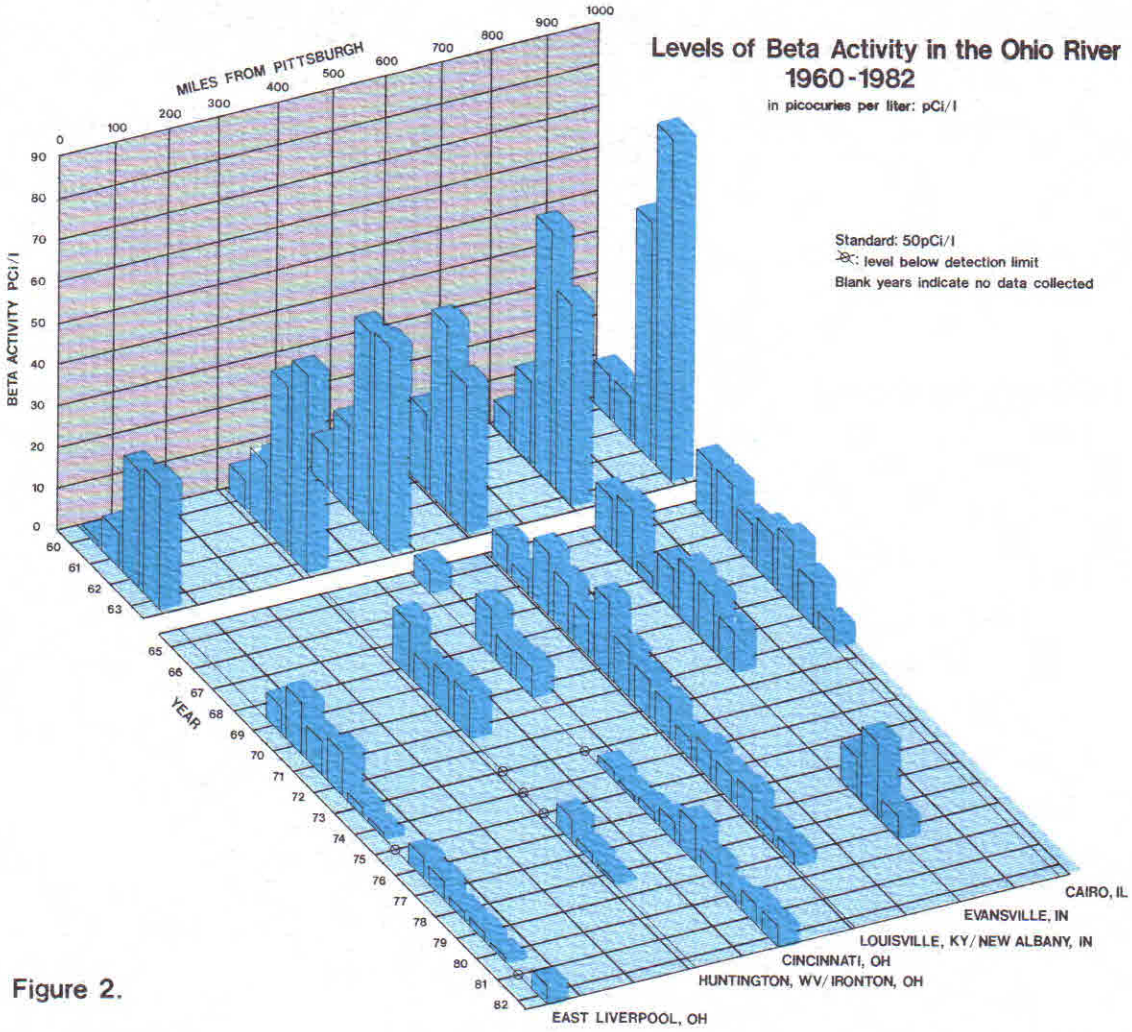


Figure 2.

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Figure 3.

Radiation

Radiation is the result of the decay of a radioactive element or radioactive isotope of an element. There are 106 known elements. Some of these are radioactive in all forms; many have radioactive isotopes.[2] Radioactive elements or isotopes undergo spontaneous transformation of the atomic structure of their nuclei to form new elements or isotopes.

Generally, radioactive isotopes and elements emit three different forms of radiation during these transformations: alpha, beta and gamma rays.[3] Alpha (α), beta (β) and gamma (Γ) are called forms of *ionizing radiation* because they can change the structure of atoms or molecules they encounter. It is this capability that makes radiation dangerous to living things. Radiation can change the structure of living tissue cells, for example, and cause cancer or birth defects. It can affect humans and other living things both externally and as an internal emitter, if inhaled or ingested in food and water.

Alpha particles consist of streams of Helium ions, which have a mass of four atomic units and a positive electrical charge of two units. Alpha particles are relatively heavy, do not travel far in air, and generally do not have enough energy to penetrate the protective outer layer of human skin. Therefore, substances that emit alpha particles are dangerous only if ingested or inhaled.

Beta particles consist of streams of electrons, the negatively charged particle in the atom. The energy of beta particles depends upon the substance which emits them. Beta particles from Strontium-90, (a radioactive isotope produced as a result of nuclear fission and a constituent of nuclear "fallout") can penetrate human skin. Strontium-90 atoms are "bone seekers"; that is, they replace calcium atoms in the skeleton. Beta particles from Tritium (an isotope of hydrogen: H_3) cannot penetrate skin and therefore, are of concern only as internal emitters. Because they were considered an index to levels of radioactive fallout, beta particle levels have been measured more extensively than other radioactive materials. The monitoring data base for gross beta in the Ohio River is larger for that reason than that of the other radioactive emissions.

Experiments have shown that a single radioactive element or isotope emits either alpha or beta particles, but not both. Gamma radiation, however, is released in all nuclear transformations. Gamma rays spread out rapidly and can penetrate solid objects. Heavy shielding at nuclear reactors is aimed at containing gamma radiation. X-rays are a form of gamma ray, as are cosmic rays.

2 An element is characterized by the number of protons in the nuclei of its atoms. An isotope of an element has the same number of protons in the nucleus but a different number of neutrons.

3 A nuclear transformation — or natural decay — of a radioactive element is very different from nuclear fission, or the induced splitting of atoms by bombardment with neutrons. With fission, much more energy is released than during nuclear transformation. This energy is released as heat. In a nuclear power plant, the heat released by fission is used to produce steam to turn turbines to produce electricity.

Figure 4

Measurement and Standards of Radioactivity

Radioactivity is measured in several ways:

The physical half-life of a radioactive element or isotope measures the time period needed for the substance to decay to half of its original activity. This figure is different for each radioactive isotope or element and is an indication of its persistence in the environment.

The biological half-life of a radioactive element or isotope refers to the time it takes an organism to rid itself of half of the original amount of the substance taken in. Generally, the longer the biological half-life of a substance, the more dangerous it is. The biological half-life is different from the physical half-life mentioned previously. For example, the physical half-lives of Strontium-90 and Tritium are 29 and 12 years respectively. By contrast, the biological half-life of Strontium-90 — or the amount of time this isotope remains in the human body before half of its concentration is excreted — is 50 years. The biological half-life of Tritium in human beings is only 10 days.

A Curie (abbreviation: Ci) measures the amount of radioactivity present in a substance in comparison to that of one gram of Radium 226.

Roentgens (abbreviation: R) measure exposure dose based upon the number of ionizations produced by x-rays or gamma rays.

A *Rad* is a measure of the amount of radiation energy *absorbed* by an object or living thing.

A *Rem,* which stands for *R*oentgen *E*quivalent *M*an, compares the number of rads emitted by a radioactive substance with those needed to produce a given effect with x-rays. Therefore, the need to specify the type of radiation is eliminated.

Curies, therefore, measure the amount of radioactivity present. *Rads* and *rems,* on the other hand, measure the dose of radiation the radioactivity delivers to an organism. In water, radioactivity is measured in picocuries per liter (pCi / l). A picocurie is one-quadrillionth of a Curie. One quadrillion is a "1" followed by 12 zeros. One quadrillionth is the equivalent of one second in more than 32,000 years.

National Safe Drinking Water Standards for beta particle activity are based upon preventing an annual dose equivalent greater than 4 millirems per year to humans from drinking water. A gross beta count in treated drinking water of less than 50 pCi / l as an annual average is considered safe, provided that the Strontium-90 level is below 8 pCi / l and the Tritium level is below 20,000 pCi / l. Ohio River Valley Water Sanitation Commission criteria are more stringent because the Commision applies the same requirements to Ohio River water — before drinking water treatment. As noted previously, drinking water treatment removes some radioactivity from water (see Criteria, Figure 5).

Figure 5.

Ohio River Valley Water Sanitation Commission

Criteria for Radionuclides

Gross Alpha	15	Picocuries per liter
Gross Beta	50	" " "
Strontium-90	8	" " "
Tritium	20,000	" " "
Radium 226 and 228	5	" " "

These criteria are identical to US EPA Drinking Water Standards except they are applied to untreated Ohio River water.

Figure 6.

Effects of Various Short-Term Doses of Ionizing Radiation on Human Health

Dose, rems	Effect
100,000	Death in minutes
10,000	Death in hours
1,000	Death in days
700	Death for 90% within months; 10% survive
200	Death for 10% within many months; 90% survive
100	No deaths, but chances of cancer and other forms of reduced life expectancy greatly increased; can induce permanent sterility in females; 2-3 year sterility in males
50	No deaths, but number of white blood cells drops below normal. If applied to male sex organs, may result in inhibition of sperm production
25	No directly observable effects

Source: Earl Cook, "Ionizing Radiation" in W.W. Murdock (ed.) *Environment, Resources, Pollution, and Society* (Stamford, Conn: Sinauer Associates, Inc., 1971); R. Curtis and E. Hogan, *Perils of the Peaceful Atom,* Ballantine Books, 1969; and the Atomic Energy Commission.

(Note: Cancer and genetic effects are usually assumed to occur at levels below those given here.)

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December, 1983

Art: Deborah Barlow

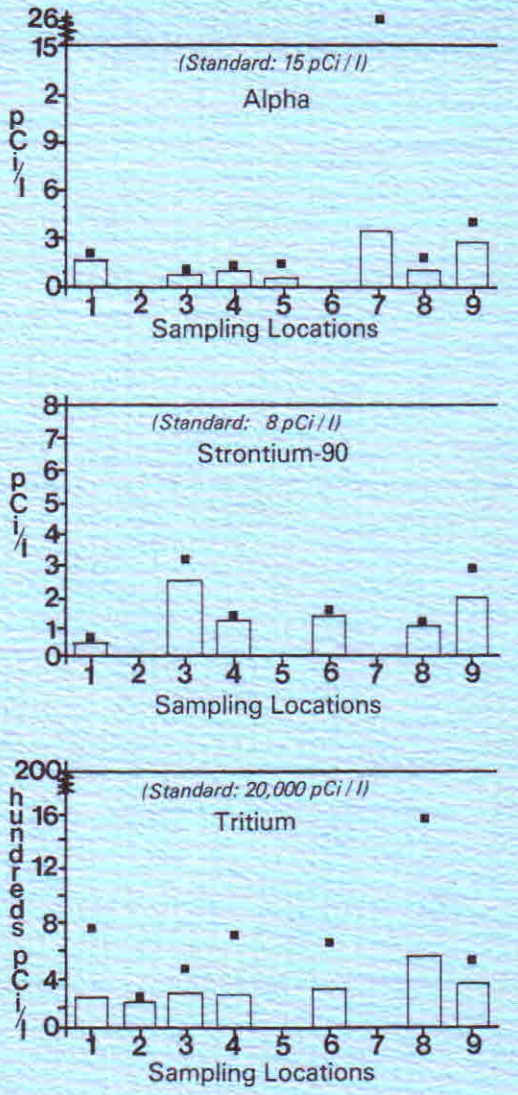
Albany, IN, area in 1967. All other values collected have been below the 50 pCi / l standard.[1]

Fewer data are available on levels of other radioactive substances in water, thereby preventing similar profiles from being developed for alpha particles and gamma emissions. Data on gross alpha and on beta emissions specifically from Strontium-90 and Tritium are available for some sites. Figure 1 provides average values for these substances over the period of record, which varies according to sampling site. Levels of alpha radiation, Strontium-90 and Tritium have basically remained well below the standards, with the exception of one sample for alpha radiation taken at Markland Dam in 1981 (25.6 pCi / l). The average values for alpha emission ranged from 0.6 pCi / l at Portsmouth, OH to 3.7 pCi / l at Markland. The maximum level recorded for Strontium-90 was 3.1 pCi / l at East Liverpool, OH, which is below the standard of 8 pCi / l. The range of averages was 0.5 to 2.4 pCi / l. Tritium, with a standard of 20,000 pCi / l, also was found only at low levels in the Ohio River. The maximum level found was 1600 pCi / l at Louisville, KY-New Albany, IN. The range of averages was 260 to 542 pCi / l.

A Final Word

The data clearly show that radioactivity is not a threat to drinking water supplies using the Ohio River as a source. Average levels of gross alpha and beta radiation are well within the limits of the standards, as are amounts of Strontium-90 and Tritium.

Because of the baseline of data on Ohio River radioactivity levels established through more than 20 years of sampling, even relatively small increases in levels can readily be detected. The monitoring programs for potential discharges along the river are, therefore, a measure of protection for the safety of water supplies.



The Ohio River flows for 981 miles from Pittsburgh, PA, to Cairo Point, IL.

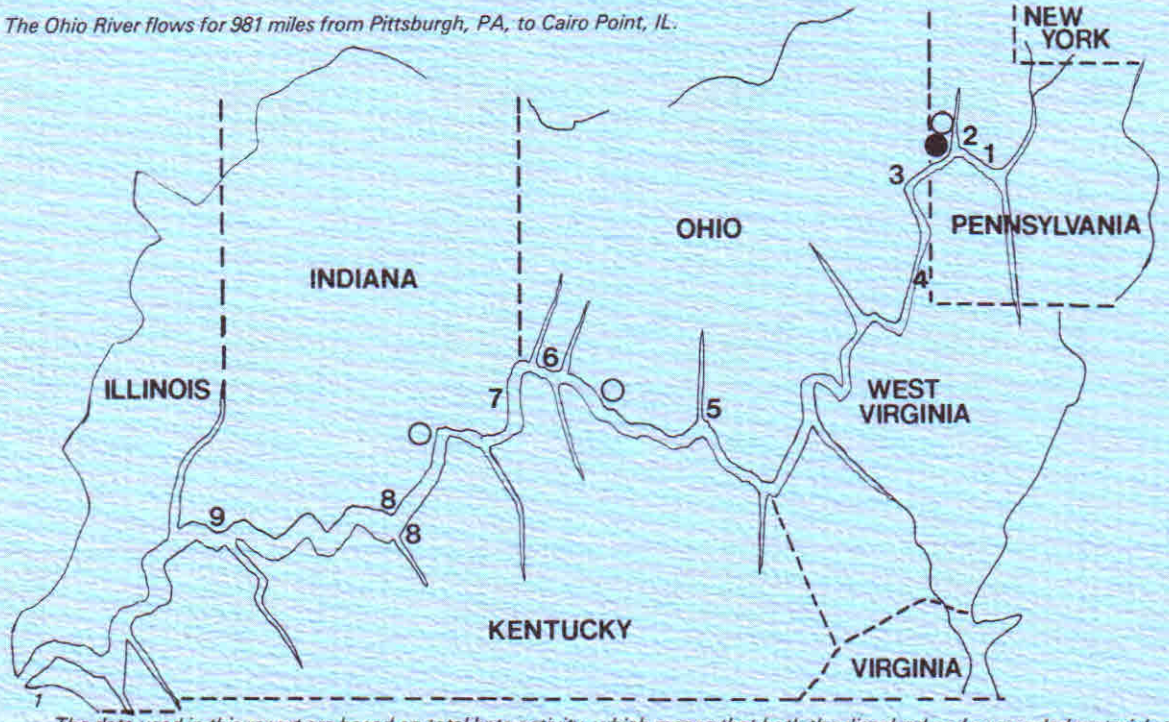


Figure 1. KEY

Sampling Locations

1 South Heights, PA
2 Beaver River, PA
3 East Liverpool, OH
4 Wheeling, WV
5 Portsmouth, OH
6 Cincinnati, OH
7 Markland Dam
8 New Albany, IN / Louisville, KY
9 Evansville, IN

▪ maximum
▭ average

no bar at a location indicates that no sample was collected there for that radionuclide

● nuclear power plants
○ nuclear power plants under construction

The data used in this report are based on total beta activity, which means that both the dissolved and suspended materials that emit beta particles are combined. This measure can be compared to the Commission standard, since that is for water taken directly from the Ohio River. However, during treatment of this water for drinking, most of the suspended particles are removed. Thus, the levels of beta in drinking water are reduced. There is no formula to precisely determine this reduction, however.

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