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Project 32.2a

THE EFFECT OF NUCLEAR EXPLOSIONS ON COMMERCIALLY PACKAGED BEVERAGES

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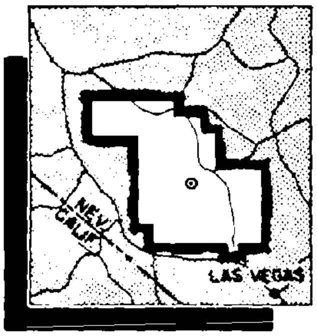

CIVIL EFFECTS TEST GROUP

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WT-1213

Report to the Test Director

THE EFFECT OF NUCLEAR EXPLOSIONS ON COMMERCIALLY PACKAGED BEVERAGES

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ABSTRACT

The plans for Operation Teapot, at the Nevada Proving Grounds during 1955, included a series of Civil Effects Tests, one of which, Project 32.2, covered the exposure of packaged food products. As this project developed, it was expanded to cover representative commercially packaged beverages, such as soft drinks and beer, in glass bottles and metal cans. Preliminary experimental results were obtained from test layouts exposed to a detonation of approximately nominal yield. Extensive test layouts were subsequently exposed during Operation Cue, of 50 per cent greater than nominal yield, at varying distances from Ground Zero. These commercially packaged soft drinks and beer in glass bottles or metal cans survived the blast overpressures even as close as 1270 ft from Ground Zero, and at more remote distances, with most failures being caused by flying missiles, crushing by surrounding structures, or dislodgment from shelves. Induced radioactivity, subsequently measured on representative samples, was not great in either soft drinks or beer, even at the forward positions, and these beverages could be used as potable water sources for immediate emergency purposes as soon as the storage area is safe to enter after a nuclear explosion. Although containers showed some induced radioactivity, none of this activity was transferred to the contents. Some flavor change was found in the beverages by taste panels, more in beer than in soft drinks, but was insufficient to detract from their potential usage as emergency supplies of potable water.

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CHAPTER 1

OBJECTIVE

The original plans for Project 32.2, Operation Teapot, primarily covered a variety of packaged food products, not specifically including beverages. However, consideration of the problems of food supply show that the needs of humans for water, especially under disaster conditions, could be immediate and urgent. At various times some consideration has been given to special packaging of plain potable water, but since packaged beverages, both beer and soft drinks, are so ubiquitous and already uniformly available in urban areas, it is obvious that they could serve as an important source of fluids.

Since no beverages such as beer and soft drinks were included in the original procurement plans, after discussions during the early field work at the Nevada Test Site, packaged beverages were obtained locally for a first layout during one of the earlier explosions, identified for purposes of this report as Shot I. The yield of Shot I was approximately nominal (a nominal atomic bomb has an energy release equivalent to 20 kilotons of TNT). The results were encouraging and led to a second layout for tests during Operation Cue, the Federal Civil Defense Administration program for the open shot of Operation Teapot. The yield of the open shot (identified in this report as Shot II) was approximately 50 per cent greater than nominal. A selection of beverages in a variety of cans and glass containers was studied under critical conditions of nuclear explosions at varying distances from Ground Zero (GZ), with particular attention to blast effects, the subsequent levels of induced radioactivity, and the ultimate potability.

CHAPTER 2

EXPERIMENTAL

Two lots of beer and soft drinks in both cans and bottles, covering a typical range of commercial products, were exposed (see Figs. 2.1 to 2.3). The first lot was placed in several layouts for testing during Shot I (Figs. 2.4 to 2.6). The container types, contents, and positioning are covered in Tables 2.1 and 2.2. The second lot was exposed during Shot II in a variety of locations similar to the other packaged foods of Program 32.2 and is itemized in Table 2.3. These tables also indicate container code designation, distance from GZ, and special exposure situations. Full instrumentation for gamma and neutron flux was obtained for distances up to 2 miles from GZ. Upon recovery, the induced radioactivity was measured in both the product and container by beta-gamma survey meters and by scintillation scalers scanning samples of the beverage placed in stainless steel planchettes.

Table 2.1 — REPRESENTATIVE BEVERAGE CANS AND BOTTLES EXPOSED TO NUCLEAR EXPLOSIONS

Metal Can Types

1. 12 fl oz, cone top crowned; contents soft drinks
2. 12 fl oz, flat top; contents soft drinks
3. 12 fl oz, flat top; contents beer
4. 16 fl oz, flat top; contents beer

Glass Bottle Types (Crown closed)

1. 28 fl oz, clear returnable; contents carbonated water
2. 12 fl oz, clear returnable; contents cola type soft drink
3. 7 fl oz, green returnable; contents lemon soda type soft drink
4. 6 fl oz, green returnable; contents cola type soft drink
5. 6 fl oz, clear returnable; contents carbonated water
6. 12 fl oz, amber export returnable; contents beer
7. 12 fl oz, amber export 1-trip; contents beer
8. 12 fl oz, clear returnable; contents beer
9. 12 fl oz, clear 1-trip; contents beer
10. 12 fl oz, amber stubby 1-trip; contents beer
11. 12 fl oz, green ale-shape 1-trip; contents ale

Note: The bottled beer and ale samples were paper wrapped in pairs to exclude light during the layout period on the desert before the test explosion, in the early investigation.
All test beverages during Shot II were exposed in closed shipping cases or on interior shelves of buildings.

Table 2.2 — LOCATION OF BEVERAGE SAMPLES EXPOSED DURING SHOT I

Position A (0.2 mile from GZ)

1. Bottles buried, crown upright (4-in. coverage)
2. Cans buried, top upright (4-in. coverage)
3. Bottles buried, on side (4-in. coverage)
4. Cans buried, on side (4-in. coverage)

Position B (0.7 mile from GZ)

1. Bottles laid on loose earth, crown toward GZ
2. Bottles laid on loose earth, base down at 45° angle
3. Cans laid on loose earth, bottom toward GZ
4. Bottles bedded in loose earth, crowns toward GZ
5. Bottles bedded in loose earth, bases toward GZ
6. Cans bedded in loose earth, bottoms toward GZ
7. Cans bedded in loose earth in upright position, top up

Position C (1 mile from GZ)

1. Bottles laid on stony earth, bases toward GZ
2. Cans laid on stony earth, bottom toward GZ
3. Bottles laid on stony earth, crowns toward GZ
4. Cans upright on stony earth

Table 2.3—LOCATION OF BEVERAGE SAMPLES FOR EXPOSURE DURING SHOT II

Station		Beer						Soft drinks					
		Cans			Glass			Cans			Glass		
Facility	Distance, ft	No.	Cap., oz	Code	No.	Cap., oz	Code	No.	Cap., oz	Code	No.	Cap., oz	Code
Trench, 3-in. earth cover	1,270	48	16	C	48	11	L	48	12	J	12	12	N
		48	12	B	48	11	M	48	12	K	12	12	C
		48	16	D				48	12	I	12	6	P
		48	12	H							12	7	Q
		48	16	F							12	6	R
		48	16	E									
		48	12	A									
Concrete shelter, on floor	2,250	4	16	F	24	11	L	16	12	J	3	12	N
		4	16	D	24	11	N	16	12	K	3	12	O
		4	16	E				12	12	I	6	6	R
		4	16	C							6	7	Q
		4	12	H							6	6	P
		12	12	G									
Concrete shelter, on shelves	2,250	4	16	F	24	11	L	6	12	J	3	12	N
		4	16	D				6	12	K	3	12	O
		4	16	E				12	12	I	4	6	P
		4	16	C							4	5	R
		4	12	H							4	7	Q
Brick house, kitchen refrigerator	4,700	2	16	F	2	11	L	2	12	J	2	12	N
		2	16	C	2	11	M	2	12	K	2	12	O
		2	16	E				2	12	I	2	6	P
		2	12	H							2	6	R
		2	12	A							2	7	Q
Precast concrete house, kitchen shelves	4,700	4	16	D	3	11	L	2	12	J	3	6	P
		4	12	B	3	11	M	2	12	K	3	6	R
								4	12	I	3	7	Q
											3	12	N
											3	12	O
White frame house, kitchen shelves	5,500	6	16	E	3	11	L	3	12	J	2	6	R
					6	11	M	3	12	K	2	6	P
								4	12	I	2	7	Q
											2	12	N
											2	12	C
White frame house, basement shelves	5,500	4	12	H	4	11	L	4	12	J	3	6	P
		4	12	A	4	11	M	4	12	K	3	6	R
		4	12	F				4	12	I	3	7	Q
											3	12	N
											3	12	O
Surface layout	5,500	12	12	A	12	11	L	4	12	I			
		12	16	E	12	11	M						
Behlen building, on shelves	6,800	4	12	A	8	11	L	4	12	J	6	6	P
		4	12	H	8	11	M	4	12	K	6	6	R
		4	16	C				4	12	I	6	7	Q
		6	16	E							6	12	N
		4	16	D							6	12	O
		6	12	B									
		4	16	F									
Behlen building, on shelves	10,500	4	12	A	4	11	L	3	12	J	3	6	P
		4	12	H	4	11	M	3	12	K	3	7	N
		4	16	C				3	12	I	3	7	Q
		4	16	E							2	12	R
		4	16	D							3	12	O
		4	16	F									
		4	12	B									

Note: The layouts listed in this table for Shot II coincide with those for the packaged food products of Project 32.2 and are fully illustrated in their photographs.

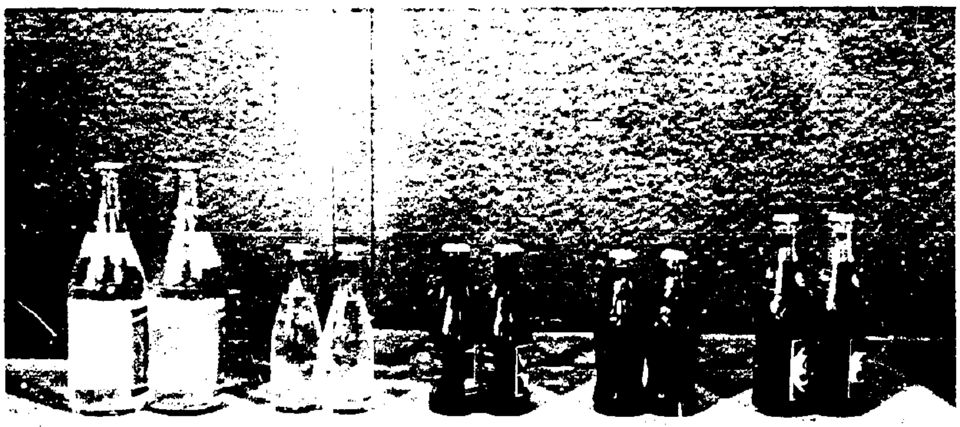

Fig. 2.1—Representative soft drink bottles exposed to nuclear explosions.

Fig. 2.2—Representative beer bottles exposed to nuclear explosions.

Fig. 2.3—Representative soft drink and beer cans exposed to nuclear explosions.

Fig. 2.4—Layout of beverage samples buried in loose soil at 0.2 mile from GZ, Shot L

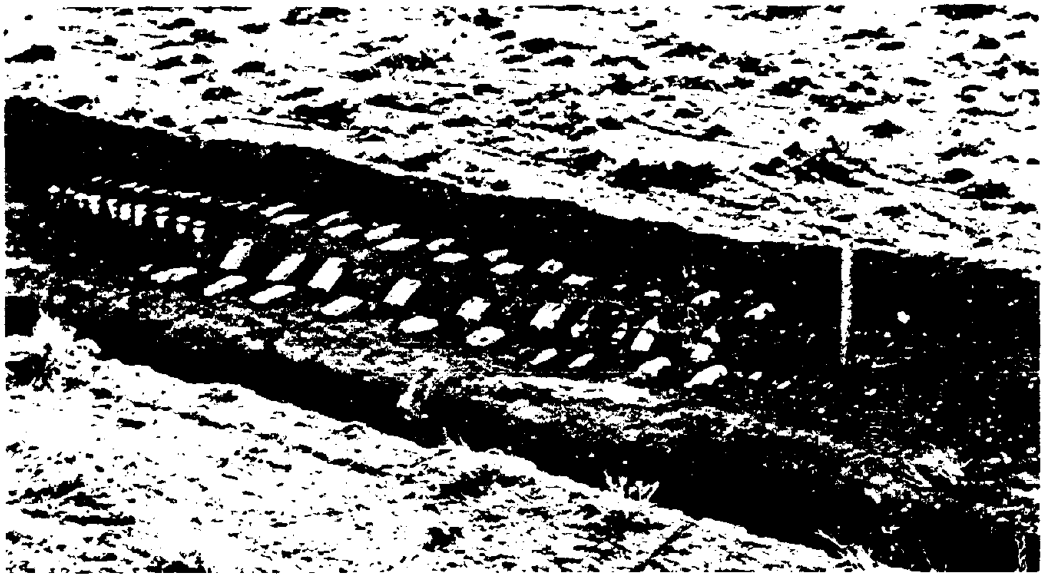

Fig. 2.5—Layout of beverage samples placed in loose surface soil at 0.7 mile from GZ, Shot L

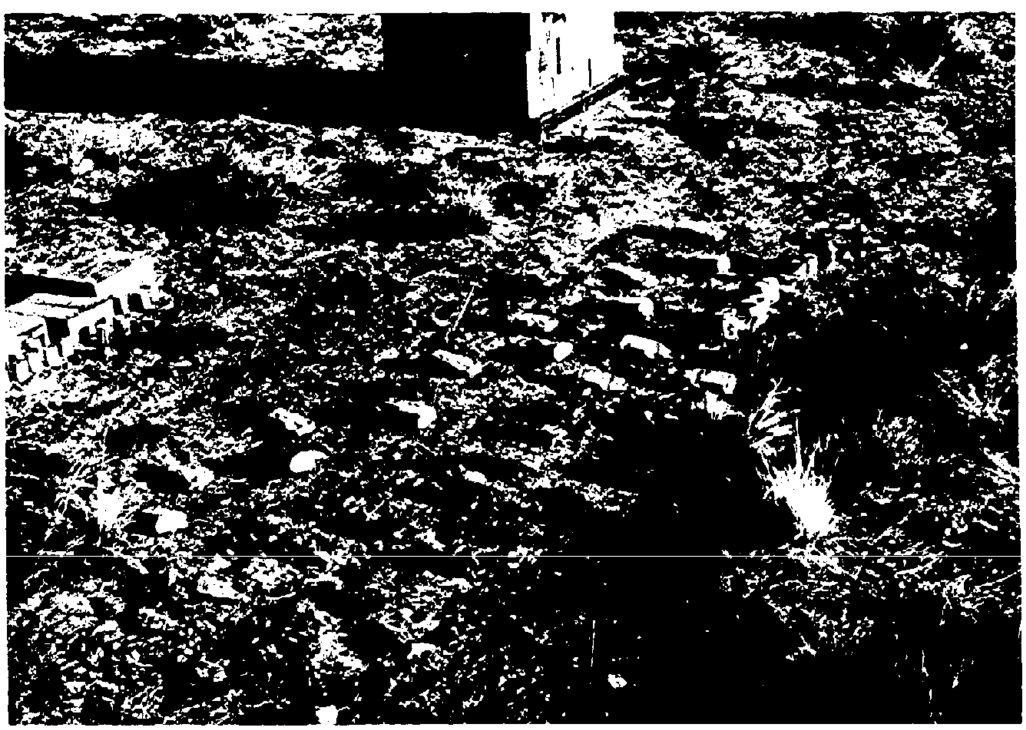

Fig. 2.6—Layout of beverage samples placed on desert floor at 1 mile from GZ, Shot L

CHAPTER 3

RESULTS

3.1 PHYSICAL EFFECTS

Under the conditions of the experiment, it was found that in the forward areas, as well as in the structures, the primary effects of blast overpressures produced only nominal losses, most of the container failures being caused by flying missiles (Fig. 3.1), severe crushing of structures in which samples were housed, and dislodgment from shelves. These effects were most pronounced on single containers. The majority of samples were exposed in commercial shipping cartons or cases which materially protected them from such damage in the various special layouts and storage conditions employed.

3.2 INDUCED RADIOACTIVITY

The beverages were recovered from the various exposed positions as early as feasible after the nuclear explosions. Measurements on these samples showed induced activity only in the forward locations. However, even the most active beverages were well within the permissible limits for emergency use and could be consumed upon recovery.

On Shot II no appreciable activity was found in exposures at 4700 ft, although the beverages at 1270 ft from GZ showed low levels. The activity of the beverages and of samples of metal plate from metal cans and bottle crowns are shown in Table 3.1. Cutting of comparable small test samples from glass containers was not possible, but scaling with a probe in contact with the whole bottle gave readings of 3000 to 4000 c/m, which declined rapidly due to the short (15 hr) half-life of Na^{24}, a major constituent.

A most important observation was that the induced activity of the beverage container, whether metal or glass, did not carry over to the contents. As shown in Table 3.1, radioactivity of contents did not vary directly with radioactivity of the container. The beverages themselves showed mild induced activity. This was due to the intrinsic properties of the product, with beer by reason of its higher natural salt content exhibiting a somewhat higher activity than soft drinks.

The labeling and decorations of the metal in cans and the crowns of bottles contain various lithography coatings and pigments. Typical samples of these various materials were exposed, and their activities are reported in Table 3.2, showing, in general, no marked difference from the metal samples reviewed in Table 3.1.

3.3 ORGANOLEPTIC CHANGES

Examination made immediately upon recovery showed no observable gross changes in the appearance of the beverages. Immediate taste tests indicated that the beverages, both beer and soft drinks, were still of commercial quality, although there was evidence of slight flavor change in some of the products exposed at 1270 ft from GZ. Those farther away showed no change.

Table 3.1 — INDUCED RADIOACTIVITY OF BEVERAGES EXPOSED DURING SHOT II IN CASE LOTS COVERED WITH 3 IN. OF SOIL AT 1270 FT FROM GZ

Code	Product and type of container	Contents* H + 136, c/m/ml	Metal disk† H + 136, c/m
A	Beer, 12-oz can	75	820
B	Beer, 12-oz can	33	722
C	Beer, 16-oz can	50	1094
D	Beer, 16-oz can	48	930
E	Beer, 16-oz can	7	550
F	Beer, 16-oz can	36	613
G‡	Beer, 12-oz can	29	998
H§	Beer, 12-oz can	42	751
I¶	Cola (dietetic), 12-oz can	15	374
J	Cola, 12-oz can	68	764
K	Root beer, 12-oz can	20	790
L	Beer, 12-oz bottle	31	444
M	Beer, 12-oz bottle	43	420
N	Cola, 12-oz bottle	12	485
O	Cola, 12-oz bottle	0	306
P	Cola, 6-oz bottle	3	314
Q	Lemon, 7-oz bottle	0	352
R	Carbonated water, 6-oz bottle	0	353

*Beverage samples transferred to a planchette (0.57 in. in diam.).
†Disk 0.57 in. in diam. punched from top end of can or crown.
‡A sample measured at H + 81 gave a reading of 170 c/m/ml.
§A sample measured at H + 81 gave a reading of 225 c/m/ml.
¶A sample measured at H + 81 gave a reading of 34 c/m/ml.

Notes: Activity in the beer appeared to have a short half-life of approximately 12 to 15 hr.
These beverages appeared to derive no induced activity from their containers.
These beverages were well within permissible limits of activity for emergency use (10-day tolerance, NIH) and could be consumed upon recovery.
Beverages recovered at H + 4 hr at the 4700-ft exposure showed no induced activity.

Table 3.2—RADIOACTIVITIES IN TEST PANELS OF COMMERCIAL EXTERIOR COATINGS OR LITHOGRAPHY FOR METAL PLATE EXPOSED BY 2-IN. BURIAL WITH ENAMEL SURFACE UP, 1270 FT FROM GZ, DURING SHOT II

Plate variable (code and element)		Description of element or drier	Coated surface of 0.57-in.-diam. disk, c/m	
			H + 40	H + 111
257-1	Aluminum	Aluminum hydrate pigment	3,300	740
257-2	Black control		3,000	730
257-3	Barium	Barium red lake C pigment	3,000	760
257-4	Boron	Borate of manganese drier	3,100	780
257-5	Boron	Boric acid	2,900	830
257-6	Cadmium	Cadmium sulfide	3,900	1,200
257-7	Calcium	Calcium lithol maroon pigment	2,800	740
257-8	Cerium and lanthanum	Rare-earth drier complex	3,000	750
257-9	Chromium	Lead chromate sulfate pigment	3,000	820
257-10	Cobalt	Cobalt naphthenate drier	3,100	620
257-11	Copper	Copper phthalocyanine pigment	3,300	620
257-12	Iron	Ferri-ferrocyanide pigment	3,100	720
257-13	Lead	Lead naphthenate drier	3,100	610
257-14	Magnesium	Magnesium carbonate pigment	2,700	610
257-15	Manganese	Manganese naphthenate drier	2,900	650
257-16	Molybdenum	Lead chromate-sulfate-molybdate pigment	2,900	740
257-18	Silicon	Sodium-aluminum-silicate pigment	2,900	680
257-19	Sodium	Sodium lithol pigment	3,100	620
257-20	Strontium	Strontium rubine pigment	3,100	630
257-21	Titanium	Titanium dioxide pigment	2,900	660
257-22	Tungsten	Phosphotungstic acid pigment with some phosphomolybdic acid pigment (rhodamine)	11,200	1,670
257-2	Zinc	Zinc oxide pigment		780

Note: The set of 22 test panels 4.5 by 5.5 in. was coated on one side only. All coatings were on electrolytic plate without a varnish. Thirteen of the panels were single-element, and the other 10 contained mixtures. Only one panel—257-22 (Tungsten)—gave evidence of high radioactivity at H + 40. The control panel gave no radioactivity. There was no indication that color had any bearing on the amount of radioactivity.

Fig. 3.1 —Missile perforation of containers exposed during Shot II.

Representative samples of the various exposed packaged beers, as well as unexposed control samples in both cans and bottles, were submitted to five qualified laboratories for carefully controlled taste testing. The cumulative opinions on the various beers indicated a range from "commercial quality" on through "aged" to "definitely off." All agreed, however, that the beer could unquestionably be used as an emergency source of potable beverages. Obviously, if a large storage of such packaged beers was to be trapped in a zone of such intense radiation following a nuclear explosion, ultimate usage of the beverages beyond the emergency utility would likely be subject to review of the taste before return to commercial distribution.

Other observations on the beer indicated some loss of color perhaps due to bleaching. Associated was a slight gain in headspace gases, other than CO_2, which was probably the result of slight decomposition of the water of the product. An occasional haze increase may have been due to modification of the soluble proteins. However, the consensus indicated that most of the changes were not much beyond those experienced after several months' storage, particularly at temperatures comparable to those of the layouts on the desert floor while waiting for the actual test.

Representative samples of the various exposed bottled soft drinks in both metal and glass containers, as well as control samples, were submitted to eight qualified laboratories, for carefully controlled taste testing. The cumulative opinions ranged from "no change" to "some aging" to "some flavor change." All agreed, however, that the soft drinks could definitely be used as an emergency source of potable beverages. In general, the soft drinks appeared to suffer less modification of character than the beer samples, probably because the latter are more complex and varied in chemical composition.

Other observations on the soft drinks indicate that the sugar, existing principally as sucrose in the fresh beverages, was inverted to dextrose and levulose by the radiation to a degree that develops normally in these beverages in about six months' or longer storage. This change can alter the original flavor somewhat but is in no way harmful to the beverage consumer. In a dietetic beverage, containing a synthetic sweetener, one laboratory ascribed the noticeable flavor change to chemical modification of the sweetener.

In all samples of beverages checked for organoleptic changes, there was good carbonation retention, indicating the maintenance of gastight sealing and hermetic closure of the containers under the conditions of blast overpressures.

CHAPTER 4

SUMMARY

In summarization, it was found that commercially packaged beer and soft drinks in cans or bottles will survive the effects of the blast overpressures such as found at 1270 ft from GZ on Shot II. Nominal losses were occasioned primarily by flying missiles, the crushing of structures, or dislodgment from shelves. Shipping cartons and cases offered definite protection from blast.

Induced radioactivity, at the forward test locations of 1270 ft from GZ during Shot II, was not great in either beer or soft drinks and would allow the use of these beverages as potable water sources for immediate emergency purposes as soon as the storage area is safe to enter after a nuclear explosion. Although the containers, whether of metal or glass, showed some induced radioactivity, none of this activity was transferred to the contents. The beverages themselves exhibited only mild induced radioactivity, well within permissible limits for emergency use.

Some flavor change was found in the beverages, more in beer than in soft drinks. However, the alterations may well be considered as equivalent in most respects to "aging" and were not found to detract from the potential usage of these beverages for emergency supplies of potable water.