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**TRIOCIDIC  
QUESTIONS  
AND  
ANSWERS**

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## EXECUTIVE SUMMARY

This document reports the results of an investigation into the suitability of a potable water disinfectant called Triocide for use by the U.S. Agency for International Development in its overseas programs. The investigation was performed during the month of October 1980 by Peter J. Kolsky, a consultant to the Agency employed by Camp Dresser & McKee, Inc. The work focussed upon the safety and effectiveness of the disinfectant itself, but did not examine or field-test entire water treatment systems incorporating Triocide. The investigation involved interviews and correspondence with knowledgeable individuals and organizations as well as literature review, but did not include additional laboratory or field testing beyond that reported by others.

The major conclusions of this investigation are:

1. Triocide disinfection providing a significant iodine residual in treated water appears a safe, simple and effective short-term emergency disinfection technology, with distinct operational advantages over other technologies currently available.
2. The operational advantages of Triocide also make the possibility of medium and long-term use attractive, but the presence of a significant iodine residual in the treated water raises questions of possible iodine toxicity. These concerns can be reduced with a reduction in iodine residual, but only with a corresponding increase in the risk of pathogen survival in treated water from subsequent recontamination.
3. The question of medium and long-term iodine toxicity is a controversial one with conflicting evidence and opinions as to the existence and magnitude of the risk. Continuous use of water with iodine residual for periods up to three weeks involves no significant hazard by any account, and continuous use for years appears unwise in the face of existing evidence and uncertainty. No exact dividing line currently exists between the above "short-term" and "long-term" periods, and decisions about "medium-term" use should reflect local conditions and the feasibility of alternative means of disinfection.

An addendum reflecting comments and questions from reviewers received since the original distribution of the report was added in March 1981.

## TRIOCIDE QUESTIONS AND ANSWERS

### WHAT IS TRIOCIDE?

Triocide is a registered trade name for a patented anion exchange resin tri-iodide ( $I_3^-$ ) disinfectant manufactured by Water Pollution Control Systems, Inc., a wholly owned subsidiary of Water Technologies Corporation, a Michigan-based firm. Triocide does not appear to be a conventional iodine disinfectant or iodinator, as results have been reported<sup>1</sup> indicating total elimination of organism concentrations as high as  $10^7$ /ml with an iodine residual of less than 0.2 ppm. Papers<sup>2,3</sup> have been published describing the action of Triocide as a "demand disinfectant" which kills bacteria with iodine released at the resin surface as bacteria come into contact with the resin, a mechanism which differs significantly from conventional chemical disinfection based upon establishing a suitable concentration of disinfectant in the effluent.

While the manufacturer claims, and can provide some lab results supporting, the ability to tailor the resin to disinfect water with the low iodine residual cited above<sup>1</sup>, EPA's registration of three forms of Triocide technology as water purifiers is based upon the provision of a significant residual.<sup>4,5</sup> Because the iodine residual provides some protection against subsequent recontamination of treated water (e.g. by a dirty cup), AID's Office of Foreign Disaster Assistance (OFDA) also specified a minimum iodine residual of 0.5 ppm in an emergency disinfection system using Triocide solicited in August 1980.<sup>6</sup> The iodine residual in water treated by Triocide is important because while it provides some "insurance" of disinfection, it also raises iodine toxicity issues when considering medium to long-term use.

### IN WHAT FORMS CAN TRIOCIDE BE USED?

Triocide is marketed on very different scales. For individual or family use, it is employed in the "Walbro Water Purifier", the "Puri-Jug", the "Maxi-Pail", and the "Water Tech 10", which are all manufactured by Water Technologies. Water Technologies has also marketed "Emergency Water Purification Systems" which are intended for larger groups, with a treatment capacity of 300 gallons per hour (gph). The solicitation for the OFDA unit specifies a nominal capacity of 2,000 gph, obtained with a parallel configuration of eight of the 300 gph Triocide cartridges used in Water Technologies' "Emergency Water Purification Systems" mentioned above.

The Walbro Purifier, Puri-Jug, and Maxi-Pail all use essentially the same technology, that is, the same amount of Triocide placed between mechanical screen filters. All three are registered with the EPA as water purifiers under the same registration No. (35917-1), and these are the only forms of Triocide which are registered with them. The Walbro Purifier carries a label approved by EPA indicating that the unit will provide "a minimum of 100 gallons of

microbiologically potable water," while the other two are registered for 1,000 gallons.<sup>7</sup> The Water Tech 10 is another unit, intended for family groups with three Triocide cartridges housed in a ceramic filter, and is intended for manufacture and sale in developing countries (with the Triocide manufactured by Water Technologies in the U.S.) The Water Tech 10 has not yet been registered with the EPA.

The larger emergency water purification systems manufactured by Water Technologies involve the same Triocide resin, but in a distinctly different configuration, with a larger Triocide cartridge preceded by a centrifugal separator or mechanical strainer and charcoal filter. The unit solicited by OFDA would precede the Triocide with a strainer, fabric bag pre-filters, and a KATADYN MF54 or equal porous ceramic filter set. These larger units have also not as yet been registered with EPA. The EPA Product Manager has indicated that registration of larger units would require separate testing; while there is no conceptual obstacle to the use of "Triocide cartridges in parallel", such a product is sufficiently different in scope from those registered as to require re-examination.<sup>8</sup>

Clearly the number of possible configurations using Triocide is virtually unlimited. The most important distinction to make for the purposes of this report is that between individual systems which would only be used for brief periods, and the family and larger-scale purification systems, which might be used for longer periods.

#### WHAT MAKES TRIOCIDE ATTRACTIVE FOR AID USE?

Triocide has certain distinct advantages over other disinfectant technologies. Because it kills bacteria as the water passes through the resin column, no subsequent detention time is required to insure disinfection. (Required contact time in the column itself is on the order of seconds.) This reduces the volume required for the system, and eliminates any concerns about "short-circuiting" of the treated water. Disinfectant application is greatly simplified, with no proportional feed system required. According to the manufacturer, and some published papers and results, the iodine residual is not required for disinfection, in contrast to conventional disinfectant technology. If these claims are true, maintaining and monitoring iodine residual might be desirable as an added assurance of disinfection, but would not appear as essential to the disinfection process as it would be for conventional chlorine or iodine disinfection.

Use of the smaller units for individual or family use also eliminates the need for supply and storage of halazone (chlorine) or globaline (iodine) tablets. The smallest unit is registered by

the EPA to provide a minimum of 100 gallons: enough as the label indicates, to provide 3 12oz glasses per day for approximately a year. The possibility of such simple home disinfection (other than by boiling) is obviously attractive.

#### HOW EFFECTIVE IS TRIOCIDAL AS A DISINFECTANT?

Tests by the inventors, or at independent laboratories paid for in most instances by the manufacturer, indicate the tri-iodide resin is effective as a disinfectant against a variety of micro-organisms. Some results, with before and after concentrations and the literature reference are cited below. Note that most such results were obtained with the Triocide resin, but not necessarily using the marketed configuration:

<u>Organism</u>	<u>Influent Concentration</u>	<u>Effluent Concentration</u>	<u>Reference</u>
	(Viable Count Per ml)		
Salmonella typhimurium	$1.0 \times 10^6$	0	2
Escherichia coli	$3.0 \times 10^5$	0	2
Pseudomonas aeruginosa	$1.3 \times 10^5$	0	2
Staphylococcus aureus	$1.8 \times 10^4$	0	2
Streptococcus fecalis	$1.1 \times 10^4$	0	2
Streptococcus bovis			
(a) encapsulated	$8.0 \times 10^5$	0	2
(b) nonencapsulated	$1.0 \times 10^5$	0	2
Bacillus cereus			
(a) unheated	$1.0 \times 10^5$	$4.5 \times 10^2$	2
(b) heated at 63°C	$2.5 \times 10^3$	$3.5 \times 10^2$	2
Bacillus megaterium	$3.2 \times 10^6$	$1.5 \times 10^6$ (all spores)	2
Micrococcus lutea	$7 \times 10^4$	0	9
Salmonella pullorum	$9 \times 10^4$	0	9
Polyoma virus (PFU)	$3 \times 10^5$	0	9
Newcastle disease virus	$2 \times 10^4$	0	9
Total coli	14	0	10
E. coli	$2.6 \times 10^5$	0 (MPN < 2, No growth)	11

As part of its registration process, EPA developed a protocol for bacteriological testing to be performed on Triocide to be reported to EPA by independent laboratories at the expense of the manufacturer. EPA also performed some tests of its own and on the basis of these tests and manufacturer's submittals, registered the Walbro Water Purifier, Mini-Jug and Maxi-Pail as water purifiers. The EPA-approved label for the Walbro Purifier indicates that it will render "relatively clear raw water microbiologically suitable for drinking...thoroughly tested against Escherichia coli in relatively clear water to provide a minimum of 100 gallons of microbiologically potable water." (Other aspects of EPA registration, labeling and approval are discussed below). The EPA Product Manager responsible for registration of Triocide has made it clear that while EPA can stand behind the claims for disinfection of E. coli, the results cited above for other organisms were not conducted under EPA supervision and therefore cannot be specifically endorsed by EPA.<sup>8</sup> The head of the Disinfectants Branch of the Registration Division has made clear on two occasions<sup>4,5</sup> that the presence of a significant iodine residual in the effluent of the Triocide unit was a major factor in its acceptance as an effective disinfectant, and that EPA could not register "low iodine residual" Triocide (e.g. less than 0.2ppm) without additional testing against a variety of organisms.

#### WHAT ARE THE TOXICOLOGICAL EFFECTS OF TRIOCIDE DISINFECTION?

The one serious toxicological concern about use of Triocide technology is the question of iodine toxicity. There appears to be a general consensus within the water supply industry that medium to long-term use of drinking water containing iodine (0.5-2.0ppm) is undesirable because of certain toxicological risks, despite the absence of EPA or WHO standards for iodine concentration. In 1973 the Director of the EPA Water Supply Division took the following position on water supplies with iodine residuals on the order of 0.5 to 1.0 mg/l:<sup>12</sup>

"In summary, the opinion of experts in the field indicates that little if any hazard to consumers would exist if disinfection with iodine were practiced on those water supplies where the consumers are transient and use the water for drinking purposes for periods of three weeks or less. Obviously it is likewise safe to use in emergency situations for the same time period or less. Because of the possibility, although rare, that continued consumption of iodinated water may have an adverse effect on individuals with impaired thyroid function or on the unborn child, iodine disinfection of public water supplies with largely permanent populations is not recommended."

A 1972 World Health Organization publication on the suitability of iodine and iodine compounds as disinfectants for small water supplies<sup>1,3</sup> stated:

".....it is clear that a prolonged administration of several milligrams of iodine per day can have adverse effects to individuals with a history of thyroid disease. The health hazards for healthy individuals seem to be low, although no data are available on the physiological effect of prolonged use over many years, especially in children.

In compliance with a statement of the American Water Works Association,\* it can be concluded that the possible toxic effects of iodine for susceptible individuals and the still unknown health hazards existing during prolonged administration of several milligrams of iodine, do not justify uses other than its emergency use as a potable-water disinfectant."

What are the specific risks involved? First, certain clearly identified risks exist for the unborn children of pregnant women and for people with impaired thyroid function. An epidemiologist at a state health department responded to a question about iodine from the chief of that state's water supply agency and noted:<sup>16</sup>

"Iodides given during pregnancy are taken up by the fetal thyroid after about the twelfth week of gestation. Daily intakes as small as 12 mg have been reported to produce congenital iodide goiters with associated hypothyroidism and mental retardation....In Tasmania, an endemic goiter area, the incidence of thyrotoxicosis doubled after the iodization of bread, with an average daily dietary intake of 80 to 270 mcg. (0.08 to .27 mg.) of iodine depending on age and sex. This increase was predominant in the older age groups among persons with toxic nodular goiter....Our review of the existing literature has failed to identify any controlled epidemiologic studies with conclusive evidence. However, available clinical evidence seems to be strong enough to support the 1973 policy issued by the EPA."

\*NOTE: The AWWA reference for this "statement" is a chapter on disinfection in the AWWA publication Water Quality and Treatment,<sup>14</sup> and not an official AWWA policy statement.<sup>15</sup>

The potential risks for these specifically vulnerable groups are reflected by the EPA-approved labelling for Triocide devices, which states "CAUTION - the possibility exists that small amounts of iodine may be present in treated water. Persons with thyroid problems and pregnant women should consult their doctor before use."

The second major concern, already noted above, is the general absence of epidemiologic knowledge about the medium to long-term effects of iodine consumption. In a 1979 review of disinfectants, the one research recommendation for iodine made by the National Academy of Sciences was for studies to determine the consequences for human health of the long-term consumption of iodine<sup>17</sup>. Widely-recognized work has been done in the Marshall Islands<sup>18</sup>, and Florida prisons<sup>19,20</sup> indicating no adverse effects from the short-to-medium term use of iodine as a disinfectant, and in 1970 Kinman et al reported:<sup>20</sup>

"No major difficulties have been encountered in using iodine for potable water disinfection during some six years and eight months of iodination of two public water supplies of 25,000 and 100,000 gpd capacities...No evidence has been found to indicate that iodine has any detrimental effect on general health in thyroid function when used as a water disinfectant."

These studies have not, however, been sufficient to alleviate professional concerns about possible toxicity effects which might not have been detected in the particular sample groups involved.

Questions of short-term iodine toxicity do not appear of concern to public health professionals. The dividing lines between "short", "medium" and "long" term usage are necessarily vague given the paucity of the epidemiological literature. No professional contacted during the course of this study, and none of the literature reviewed, expressed any concern over the use of iodine as a disinfectant for periods of less than three weeks in duration. Dr. Reto Engler, head of the Disinfectants Branch of the EPA Registration Division, and the individual responsible for toxicological review of Triocide during registration, indicated he would have significant toxicological concerns for normal individuals about the use of iodinated water or water treated by Triocide with significant iodine residual for periods on the order of two years in duration. These concerns are based on the lack of available data rather than a prediction of specific ailments. When asked about use for a period on the order of two months, Dr. Engler indicated uncertainty in the face of the existing paucity of data.<sup>4</sup>



Dr. Eric Mood, an epidemiologist at Yale University, expressed belief that use of iodinated water by normal individuals for short periods involved no significant risks, and that undesirable effects would probably not show in exposures as short as two months. Dr. Mood, however, did feel that iodine impact in accelerating human metabolism was a basis for epidemiological concern in the use of iodine other than as an emergency disinfectant.<sup>21</sup>

Both conversations and literature reviewed indicated the difficulty in putting a time limit on iodine usage because of both the lack of epidemiological evidence and the variability in iodine intake from other sources. All professionals contacted appreciated the difference in relative risk assessment in developing countries and the U.S., and none indicated that "long-term consumption of iodinated water will definitely produce health problems in normal individuals." The concerns about medium and long-term usage by normal individuals are based simply on the relatively limited knowledge of its effects.

#### WHAT PRETREATMENT IS REQUIRED FOR TRIOCIDAL DISINFECTION?

Raw water characteristics that could be expected to influence Triocide performance include turbidity, iron concentration, salinity, pH and temperature.

Water must be relatively clear and free from turbidity. This can be controlled in the larger units by ceramic filtration or centrifugal solid-liquid separation prior to Triocide disinfection. Systems can easily be designed so that filters and screens would clog before any risk of inadequate disinfection due to excessive turbidity could occur.

Iron removal would also be required for water with significant iron concentrations, as the fouling of the Triocide resin with iron compounds could otherwise be anticipated.<sup>22</sup> This presents no insurmountable problem, as iron removal is easily accomplished by aeration and filtration, but could necessitate double pumping of the water (once for aeration, and once again through the treatment system).

The labelling for EPA-registered products bears the warning that water should not be brackish (salty). This warning was proposed by the manufacturer and not by EPA, and was intended to show that Triocide does not desalinate water.<sup>22,23</sup> The manufacturer claims that Triocide can disinfect sea water, but cannot render it potable in terms of reducing salinity.<sup>22</sup> Another cause for concern about brackish water, however, would be the higher iodide ion concentrations released in treated water as raw salinity increases. In one test for example, total iodine species increased from 0.50 ppm to 5.70 ppm as chloride concentration rose from 0 to 250 ppm.<sup>3</sup>

The release of iodine species is insensitive to variations in pH below 8, and increases between pH 8 and 10, but only to a value of 4.5 ppm at most. (Higher pH would possibly release more iodine, but would rarely be encountered in practice.) Iodine release is also insensitive to temperature variations encountered in practice, and neither variation in pH nor temperature appear to influence the disinfectant capability.<sup>3</sup>

#### WHAT IS THE SIGNIFICANCE OF EPA REGISTRATION OF TRIOCIDE?

The Federal Insecticide, Fungicide, and Rodenticide Act of 1972 (FIFRA) requires that, with certain limited exceptions, all pesticides distributed or sold within the United States be registered with the Environmental Protection Agency. Triocide is considered a pesticide and is registered (Registration No. 35917-1). Other disinfectants including chlorine, are also registered under FIFRA with the EPA by the Disinfectants Branch of the Registration Division. Registration approval by the EPA signifies that:<sup>24</sup>

- "(A) its composition is such as to warrant the proposed claims for it;
- (B) its labelling and other material required to be submitted comply with the requirements of this Act;
- (C) it will perform its intended function without unreasonable adverse effects on the environment; and
- (D) when used in accordance with widespread and commonly recognized practice it will not generally cause unreasonable adverse effects on the environment."

In its registration of Triocide, the Disinfectants Branch of the Registration Division developed a protocol for bacteriological disinfection testing, which was employed by independent laboratories in testing the Triocide products at the manufacturer's expense. Some limited testing was also done within EPA. All EPA approved tests involved the testing only of E. coli, which were held sufficient given the presence of a significant iodine residual. If the same products were marketed with an iodine residual of less than 0.2 ppm, Dr. Engler has indicated that the product would have changed sufficiently to require separate registration, and more extensive testing against a wider range of bacteria and viruses. While the manufacturer's claim that the Triocide systems are the only ones registered as "water purifiers" is true, Dr. Engler indicated that chlorine-based disinfection technologies are registered with the EPA, and that there was no particular significance to the classification of Triocide as a "purifier".<sup>5</sup>

## WHAT ARE THE MAJOR CONCLUSIONS OF THIS INVESTIGATION?

Triocide, as packaged in the three products registered with the EPA, appears a safe and accepted technology for short-term emergency water disinfection for use by the general public. The major constraint upon its acceptance as a medium to long-term disinfectant is the question of iodine toxicity. While pregnant women and those with impaired thyroid function have been clearly identified as segments of the population at relatively high risk from medium to long-term exposure to low levels of iodine, there is also considerable opinion that insufficient evidence is available to exclude the possibility of long-term toxicity effect in normal individuals. The question of iodine toxicity is a controversial one about which few authorities will make categorical statements, but also one which has raised sufficient concern among responsible agencies to discourage the use of iodinated water supplies as anything but a short-term emergency measure. While the Triocide technology being developed which reduces iodine residuals would reduce or eliminate these risks, they would also result in a corresponding reduction in assurance of disinfection; it is for this reason that EPA would require separate registration of this technology. Iodine residual could also be removed by following the Triocide with activated carbon<sup>7</sup>, but the tradeoff between disinfection assurance and toxicity considerations would remain.

The dividing line between "short" and "medium to long-term" use of drinking water with significant iodine residuals is vague, given the great variety of other sources of iodine in diet and the uncertainty of the epidemiological literature. The use of iodinated water certainly appears justifiable for periods up to three weeks given the acceptance of this period by the EPA in this country. Use for long-term periods (i.e. years) appears undesirable at present where other alternatives are feasible in the face of existing evidence and concerns about toxicity. Where to draw the line between these extremes is a subject of controversy between toxicologists. While Dr. Engler indicated use for a couple of months was "marginal" he also indicated that this was only his opinion, and that differing opinions could easily be found.<sup>4</sup> (The U.S. Army, for example, continues to use iodine tablets in situations where "Engineer treated water" is not available, after re-examining the toxicity issue in 1976; such use could easily extend beyond two months. The findings of Kinman *et al*<sup>20</sup> and others can also be cited by iodine proponents.)

The use of Triocide in short-term emergency situations, where toxicity is not a factor, does offer significant advantages over other disinfection techniques currently available. The elimination of requirements for chemical feed systems, residual monitoring to insure disinfection, and adequate contact times greatly simplifies the task of water disinfection under emergency conditions, thus reducing the risk of disease due to operational error or malfunction. These benefits are unique to Triocide and should be seriously considered in selection of short-term emergency disinfectants.

In summary, the evidence accumulated during this study indicates the following:

1. Triocide disinfection providing a significant iodine residual in treated water appears a safe, simple and effective short-term emergency disinfection technology, with distinct operational advantages over other technologies currently available.
2. The operational advantages of Triocide also make the possibility of medium and long-term use attractive, but the presence of a significant iodine residual in the treated water raises questions of possible iodine toxicity. These concerns can be reduced with a reduction in iodine residual, but only with a corresponding increase in the risk of pathogen survival in treated water from subsequent recontamination.
3. The U.S. EPA, an agency characterized by a justifiably conservative approach to the public health of the American people, has stated that there appears to be no significant health risks from the continuous use of iodinated water for periods of up to three weeks. Other opinions indicate longer periods before any possible ill effects could occur, and some see no hazard at all. Any possible hazards beyond the three week estimate would vary with the concentration of the iodine residual, length of exposure, and such local characteristics as diet. Continuous use for three weeks or less certainly appears to involve no significant risk, while continuous use for years appears unwise in the face of existing evidence and uncertainty. Where to draw the line in between depends upon local conditions and the feasibility of alternative means of disinfection.

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