Polycide

technical data and literature

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1.0. Introduction

After many years of research, Frans Egstorf who is an expert in the fields of ion-exchange technology and iodine, developed Polycide, based on an ion-exchange resin and a special prepared iodine compound, to be used for waterdisinfection.
Innorec Research B.V. cooperated with this development and gave extensive support.
Polycide is now ready for market introduction.
Innorec Research is producing Polycide and has sufficient manufacturing capacity to meet the market demand.
In Indonesia a Polycide production plant will be set up by PT Indores.

Polycide is a insoluble surface contact disinfectant, which in contrast to disinfection with chlorine, bromine and iodine solutions, releases germicide on demand.

A demand-type disinfectant means that Polycide automatically releases more or less iodine depending on the bacteria load.
The water to be disinfected has to be lead through a column filled with Polycide.

For the convential way of disinfection by chemical action, between 500 and 5000 µg/l (depending on the halogen used) is necessary. A solution of the halogen has to be added to the water to be treated. Contact time in practice is about 30 minutes.

In terms of the disinfection mechanism, disinfection by chemical action and by a demand-type disinfectant cannot be compared.

The application of Polycide is very attractive in small systems that treat the amount of water needed for consumption purposes. Main applications can be found in individual waterdisinfection units, household units, water disinfection units at village level and units to disinfect all the amount of water needed in temporary settlements, ships, hotels and offices.

In many countries, especially third world countries, the tapwater is contaminated with micro-organisms and has to be disinfected before consumption.
Boiling is the most common method, but the water quality deteriorates and the energy costs are relatively high. Bottled water is a very expensive alternative.

Compared with chlorine(compounds), the application of Polycide does not need any dosing equipment, hardly any maintenance and no skilled operators. The investment for a disinfection unit is relatively low. Water that has been treated with Polycide has an excellent taste.

For areas where the polulation already has a sufficient iodine intake, the "Zerocide"-resin has been developed to remove the small amounts of iodine and/or iodide from the Polycide effluent water.

2.0. Summary

Based on Polycide, we present in this paper the results of tests executed by:

- DHV Consulting Engineers B.V., Amersfoort (the Netherlands);
- the Department of Microbiology, Africultural University Wageningen (the Netherlands);
- the Department of Microbiology, the University of Amsterdam (the Netherlands);
- a microbiologist from a hospital in Bandung (Indonesia);
- the Department of Health on pathological examination of water samples (South-Africa).

Regarding the question of possible health effects that may occur, we present the results from an extensive literature search and from research outcomes by others.

3.0. Subjects

This is a summary of different testprograms that have been carried out based on Polycide.

3.1. "Disinfection based on iodine loaded resins"

(Desinfectie met een met jodium beladen kunsthars), june 1986, R. Brinkman, DHV Consulting Engineers B.V., Amersfoort (the Netherlands).

3.1.1. Introduction

Based on Polycide, DHV investigated at its water treatment laboratory:

- the disinfecting effectivity of Katadyn ceramic filters;
- the lifespan of Polycide, with a Katadyn filter as prefiltration, to be sufficient for a economic feasible application;
- the amount and variation of iodine in the Polycide effluent water.

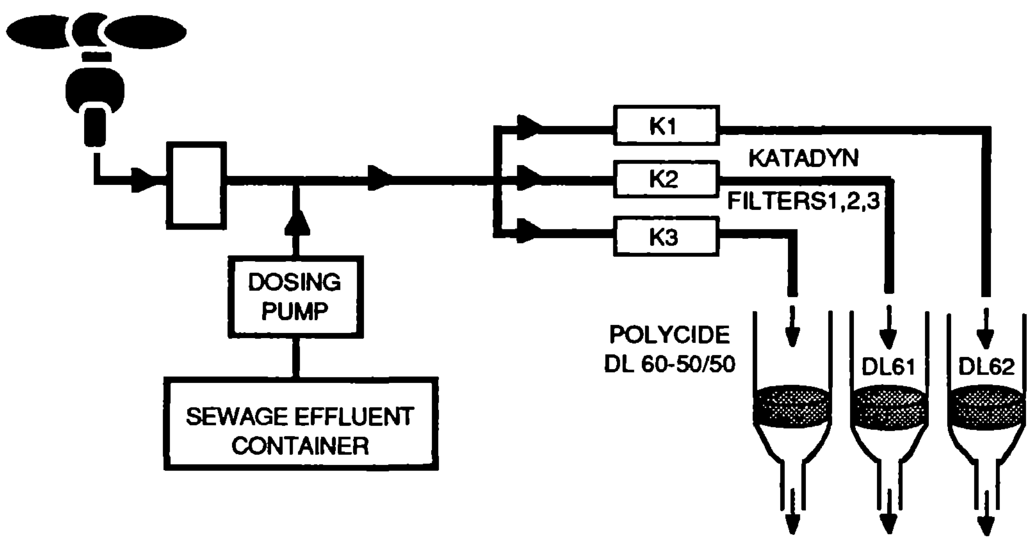
In a desk study DHV made sketches for household units based on Polycide, to be used in third world countries with contaminated tapwater.

3.1.2. Methods

Test protocol:

One part effluent water from a sewage water treatment plant was taken and mixed with 500 parts of tapwater.
As a prefiltration step Katadyn ceramic filters containg silverquartz were used.
The filtered water was lead, downflow, through three columns containing 100 ml. Polycide DL 60-50/50, DL 61 and DL 62. After 34.000 bedvolumes the test was continued in an upflow mode.
Because of air bubbles formation and an amount of iodine in the effluent water > 1 ppm, the test for the experimental type DL 62 has been abandoned.
For the test set-up, see figure 1.

Figure 1:



Water samples have been taken from the:
- Katadyn filter influent;
- Katadyn filter effluent;
- effluent from the columns filled with Polycide.

To detect the number of E-coli, 100 ml samples were taken and filtered through a membrane under vacuum. The whole filter was incubated on an agar plate (24 hours incubation at 44° C).

To detect the colony number, 1 ml water samples were inoculated on agar plates (24 hours incubation at 22° C).

In the effluent water from the columns filled with Polycide, the amount of iodine was detected, using orthotolidine and a spectrofotometer (Merck Spüren Analyse).

3.1.3. Results

Pre-filtration

The influent water (sewage + tapwater) contained 800-1000 E-coli bacteria /100 ml and a colony-number of 2000-3000/ml (22° C).
After about 500 litres of influent water, the colony-number from the Katadyn filters effluent water was found to be > 100/ml. (22° C).
Cleaning the surface of the Katadyn filter with a brush had hardly any influence on the microbiological quality of the effluent water (colony number).

The amount of E-coli bacteria (44° C) and the colony-number (22° C) of the Katadyn filter influent and effluent water, related to the amount of water that passed (in litres) is shown in table 1.

Table 1: Disinfection with a Katadyn filter:

water in litres	E-coli 44° (/100 ml) influent	E-coli 44° (/100 ml) effluent	col. numb. 22° (/ml) influent	col. numb. 22° (/ml) effluent	remarks
36	848	0	656	14	* = candle cleaned with brush
106	892	3	608	45	
248	106	0	564	28	
327	808	0	2600	54 #	# = as influent fresh sewage effluent was taken
523	832	0	2400	104	
798	232	0	1500	424	
1015	952	0	1800	368 # *	
1308	-	-	2600	648	
1549	1008	1	2500	712	- = no E-coli count
2141	872	0	2500	824 #	
2796	1032	0	3000	1044 # *	
3245	976	0	2000	992 #	o = no colony number count
3942	-	0	2400	1024 #	
7700	-	-	o	600	
9100	-	-	o	650	
9900	-	-	o	650	
11100	-	-	o	200	
11600	-	-	o	200	

Inactivation results with Polycide

At a maintained contact time of 15 seconds, the effluent water from the Katadyn filter was lead through two columns filled with Polycide DI 60-50/50 and DL 61.
For each type of Polycide, 10 water sample were taken from the effluent at 15 and 30 seconds contact time.
After passage of the two columns with Polycide, the colony-number per 100 ml (22° C) that has been detecected, at 15 and 30 seconds contact time, is shown in table 2.

Table 2: Disinfection with Polycide DL 60-50/50 and DL 61, at 15 and 30 seconds contact time

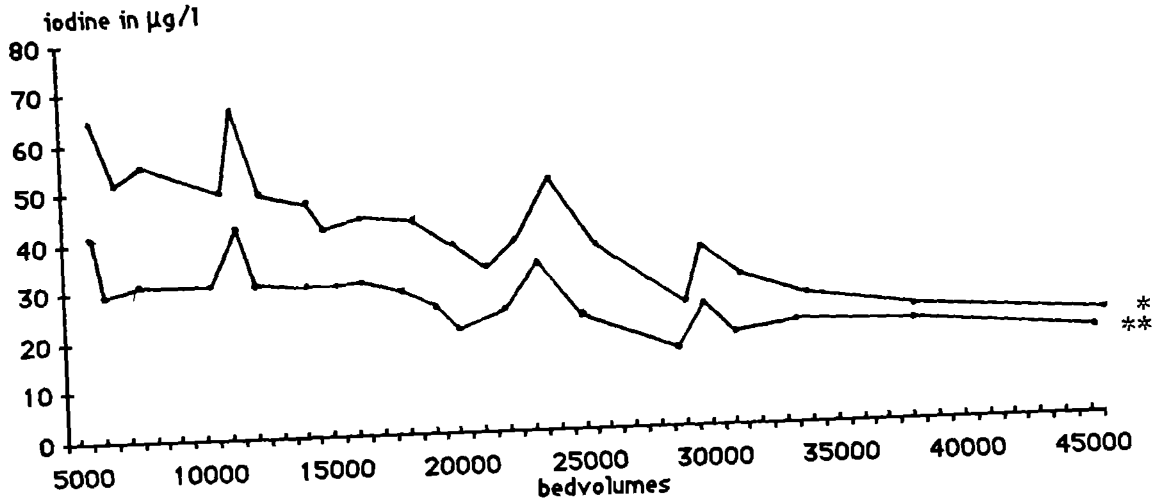
	colony number/ml, 22° C			
	Polycide DL 60-50/50		Polycide DL 61	
Bedvolumes	15 seconds	30 seconds	15 seconds	30 seconds
6020	0	4		
6060			3	0
9310	0	0		
9710			1	0
11860	0	1		
12020			0	1
13990	1	0		
14180			0	0
17150	0	0		
17480			1	0
110500	0			
111500			0	
116000	0			
117000			2	
124000	0			
125000			0	

Amount of iodine in the Polycide effluent water

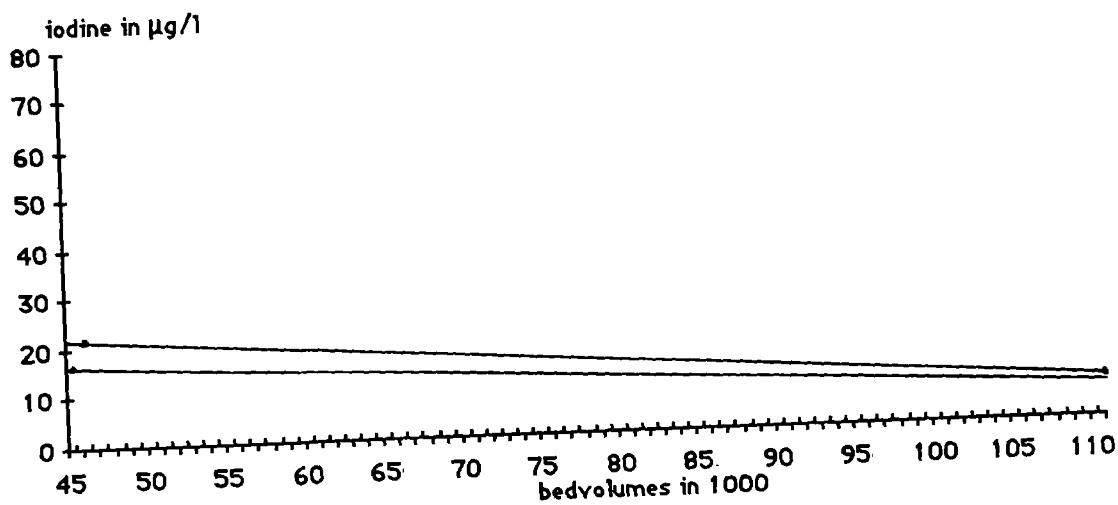
The amount of iodine in the effluent water (µg/ltr) at a contact time of 15 seconds, related to the amount of Polycide-bedvolumes of water that has been disinfected, is shown in figure 2.

Figure 2: Amount of iodine (µg/l) in the Polycide effluent water.

from 5.000 to 45.000 bedvolumes



from 45.000 to 110.000 bedvolumes



* Polycide DL 61

** Polycide DL 60-50/50

from 110.000 to 125.000 bedvolumes

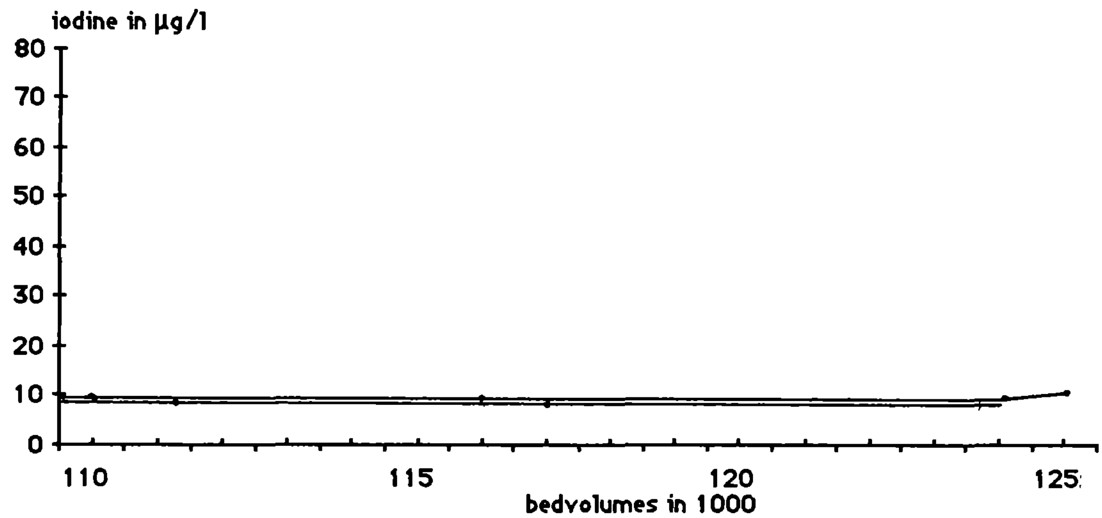


Table 3: the amount of iodine in the effluent water (µ gram/litre), at different contact times .

contact time (seconds)	iodine in µg/l DL 60-50/50	DL 61	remarks
15	28	52	after 6600 bedvolumes
30	33	62	
60	35	65	
120	31	54	
15	39	64	after 11000 bedvolumes
30	41	67	
60	34	60	
120	32	51	
15	21	35	after 20000 bedvolumes
30	24	34	
60	21	37	
120	21	33	

3.1.4. Deskstudy results:

For application of Polycide in household disinfection units to be used in third world countries, in figures 3 and 4, the following sketches have been worked out.

Figure 3:

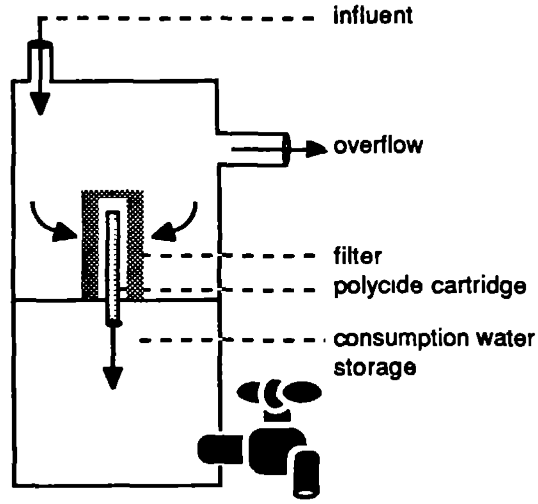
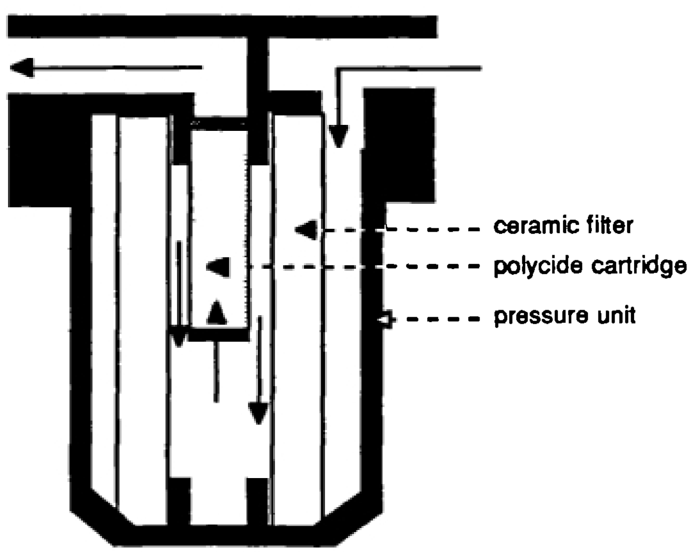


Figure 4:



3.1.5. Discussion:

A Katadyn ceramic filter removes E-coli bacteria, but leads to an insufficient reduction of the colony number.
This means that the water treated, is not reliable in terms of microbiological quality.

At 130.000 Polycide-bedvolumes the disinfecting capacity of the two columns with Polycide was still outstanding. The test was then stopped, because at this capacity level an economic feasible implementation can be realised.
It seems possible that with one litre of Polycide more than 500 cubic meters of water can be disinfected. A condition for this will be a good pretreatment of the water before entering a column filled with Polycide. DHV suggests to use Polycide in household disinfection units, that treat the amount of water needed for consumption purposes only. Main applications could be found in third world countries with contaminated tap-water.

Annex: WHO guidelines for biological and microbiological water quality.

3.2. The inactivation of E-coli E 4 with iodine resin

(De inaktivatie van E-coli E 4 door jodiumhars) december 1986, Marianne H. Donker, Department of Microbiology, Agricultural University Wageningen.

3.2.1. Introduction:

Based on a column with Polycide DI 60-50/50, experiments have been executed to find answers to the following questions:

- what is the activation energy (= Ea) of the Polycide disinfection process ?
- what is the inactivation capacity of Polycide ?
- how much residual iodide can be measured per inactivated E-coli E 4 ?
- are there differences between the amount of organic matter entering and leaving the column ?
- what is the effect of an elevated salt concentration on the amount of iodide in the effluent water?

3.2.2. Methods:

At different contact times and temperatures, Escherichia coli E 4 NTC 9002 were inactivated after passage through a column with Polycide.
For the first two experiments a glass column, with a volume of 10 ml Polycide was used. For experiment 3, 4.4 ml Polycide. The rest of the experiments were based on 1.14 ml. The suspensions (ph 7.2) of continuously cultivated E-coli E 4 were pumped in an upflow mode through the Polycide column.

To detect the total bacterial concentration different methods have been used:

- detecting the optical density of the culture, with a Vitatron spectrofotometer at 665 nm.
- measuring the amount of protein, according a modified version of Lowry.
- measuring the Total Organic Carbon (TOC), with a Beckman Model 915A TOC-analyser, and recording the peaks.

To detect the number of surviving bacteria E-coli E 4, the suspensions were diluted and inoculated on Endo agar plates (two days incubation at 30° C.). The plate counts determined the cell concentration as base for the Ea-calculation.
This turned out to be the most reliable method for the determination of the reaction rates at various temperatures.

Based on plate count results, using Chick and Watson's equation, the reaction rate constants were calculated.
By means of an Arrhenius-plot, the activation energy (= Ea) of the Polycide disinfection process was calculated.

3.2.3. Results:

Contact-time and survival of E-coli E 4

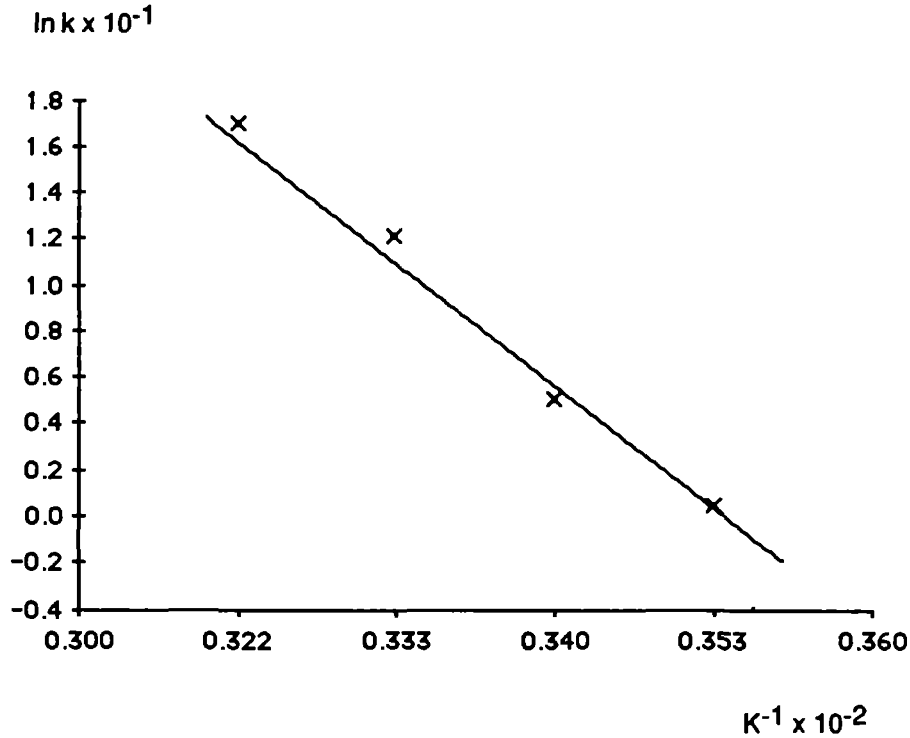
At a concentration of $\leq 10^9$ bacteria/ml, a contact-time of two seconds resulted in complete inactivation. To detect surviving bacteria in the effluent a concentration of $> 10^9$ bacteria/ml had to be used.

Activation energy during the inactivation of E-coli E 4

The Ea during the inactivation of E-coli E 4 by chlorine has been found to vary between 12 and 15 kcal/mol., Fair et al. (1968).
The Ea during the inactivation of E-coli by iodine-resin has been calculated by Kao (1972), 29 kcal/mol. and Tawaratani (1976), 19.3 kcal/mol.

In this research project, the Ea during the inactivation of E-coli E 4 by Polycide DI 60-50/50 was calculated to be 0.554 kcal/mol.

Figure 5: the Arrhenius-plot used for the calculation of the Ea. The logaritm of the reaction rate (ln k) as a function of the inverse temperature (K^{-1}). The activation energy for the inactivation of E-coli E 4 by Polycide is calculated from the tangent.



At a relative low Ea, the reaction rate is determined by the transport of the disinfecting medium towards and through the cell-membrane (diffusion limitation).

At a relative high Ea, the reaction rate between the disinfecting system and the bacteria cells becomes the limiting factor. This is due to the fact that at high Ea levels the concentration of the disinfectant becomes more important. This implies that the reaction rate becomes dependent both on cell and of disinfectant concentration.
A shift from first order towards second order kineticts is the result.

Inactivation capacity of Polycide DI 60-50/50:

After 3 representative experiments, a column with 0.95 ml. Polycide did not inactivate anymore.
Taking into account the the amount of 0.95 ml. Polycide and the total amount of bacteria that have been passed and inactivated, the column capacity was calculated.
During these 3 experiments 2.26 x 10^{12} E-coli have been inactivated, resulting in a release of 1.41 x 10^{20} iodide ions (see table 2).
The conclusion is drawn that 1 ml. of Polycide is able to inactivate 2.3 x 10^{12}
E-coli E 4. This means that, in theory, 1 ml of Polycide is able to disinfect 25 cubic meters of water, at a concentration of 10^5 E-coli/ml.
In this case, the effluent water will contain 0.01 μmol I^-/I^-.

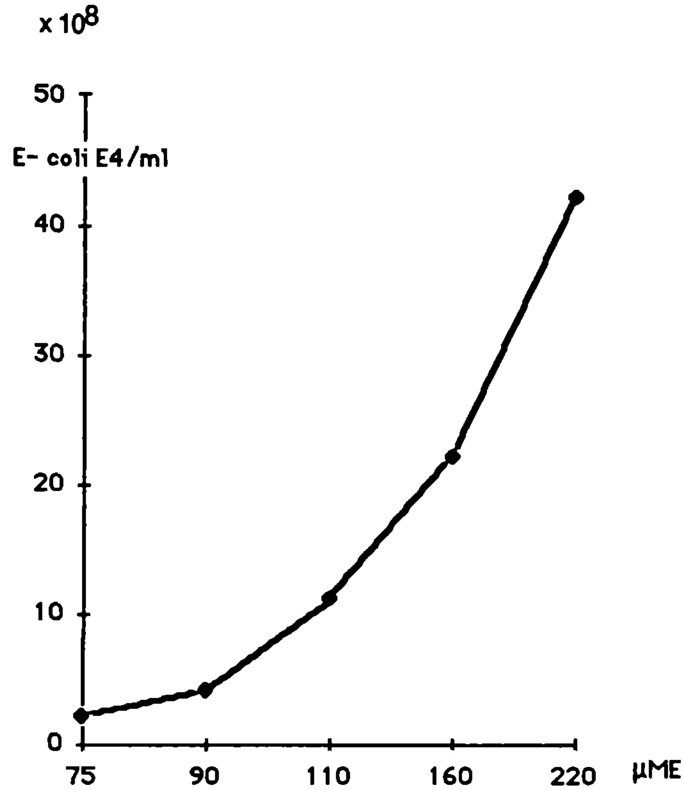
Table 4: The number of E-coli E 4 inactivated by Polycide and the release of I^- per cell are related to each other, in order to determine the capacity of 0.95 ml Polycide.

	number of inactivated E-coli E 4	I^-/E-coli E4	total iodide ion release
experiment 6	336 x 10^9	2 x 10^8	6.72 x 10^{19}
experiment 7	819 x 10^9	4 x 10^7	3.24 x 10^{19}
experiment 8	1.110 x 10^9	3.7 x 10^7	4.11 x 10^{19}
Total	2.256 x 10^9		14.1 x 10^{19}

Iodine, iodide and organic matter in the effluent water

In the effluent water, with the orthotolidine assay from Merck no iodine could be detected.
Per inactivated E-coli E 4 a iodide residual between 1.5 and 4 x 10^7 I^-ions was derived (AgNO3 and KSCN titration). This is two to four times more as presented by Suzuki & Fan (1979): 4.8.10^6 I^-ions per cell. They used a theoretical model based on sulfhydril oxidation, for their calculation of the amount of iodide per inactivated bacterial cell.
For the release of iodide ions as function of the bacteria concentration (20° C), see figure 6.

Figure 6: the iodide concentration (µM) as a function of the number of E-coli E 4 per ml at 20° C usin a contact time of 10 seconds.



Organic matter in column influent and effluent

The amount of organic material that enters the column is about the same amount that leaves the column. After ^{14}C labeling Fina & Lambert (1975) measured 90% of the ^{14}C in the column effluent.
For the total amount of organic carbon in the cell suspension (in ppm C), before and after column passage, see table 5.

Table 5: organic carbon in cell suspension (in ppm C), before and after column passage.

Experiment	6	7	8	9	10	11	12	13	15
Before passage	29	40	46	80	194	416	88	318	418
After passage	23	35	55	50	158	396	92	330	392

Salt-effect on I^- concentration in Polycide effluent water

The effect of a solution of 30g $NaHCO_3$/l on the iodide in the effluent water from the Polycide was measured.
This resulted in an release of 0.103 mMol iodide per gram of Polycide.

3.2.4. Discussion:

The effectivity of Polycide was above expectations.
Even at a contact time of 2 seconds, E-coli E 4 concentrations between 10^8/ml and 10^9/ml were completely inactivated.
The low activation energy (Ea) of 0.554 kcal/mol that has been calculated cannot be explained from differences in redox potentials between I_2, Cl_2 and O_3.
More k values could be measured at temperatures between 5°C and 40°C, for a more detailed measurement of Ea.
The influence of soluble organic matter on the inactivation kinetics and on the iodide effluent should be further studied. More information about the actual inactivation mechanism could possibly be obtained by studying the influence of Polycide on the enzymes in the cell's membrane.

3.3. Additional test-results

3.3.1. Screening tests to inactivate Klebsiella pneumonia NCT 418 bacteria (1983):

Dr. O.M. Neijssel from the laboratory of microbiology at the University of Amsterdam performed tests based on different types of Polycide.
At a influent concentration of 2 x 10^7 Klebsiella pneumonia NCT 418, two types of Polycide gave a 100% inactivation (24 hours at 37° C).

3.3.2. Screening tests to inactivate Salmonella Typhi and Vibrio Cholera El Tor bacteria (1985):

Dr. Moeliono, microbiologist at the Borromeus Hospital in Bandung (Indonesia), performed tests with Polycide.
A concentration of 5.10^6 Salmonella Typhi/100 ml and a concentration of 3.10^6 Vibrio Cholera El Tor/100 ml, passed a column filled with 10 ml. Polycide, at a contact time of 4 minutes.
In the effluent no surviving bacteria could be traced (24 hours at 37° C).

3.3.3. Screening test to inactivate Coliform organisms and Faecal E-coli (1986):

The Department of Health on pathological examination of water samples (South-Africa) tested Polycide with river water at different contact times. Even at immediate flow, all Coliform organisms (1400/100ml.) and Faecal E-coli (450/100ml.) were completely inactivated.

3.3.4. Air disinfection with Polycide (march 1986):

Ir. H. J. Brons (Department of Microbiology at the Agricultural University Wageningen) tested Polycide for air disinfection.
During two weeks room-air was pumped through a glass column with 5 ml dehydrated Polycide.
The treated air was lead through a sterile 10 litre volume glass-vessel, containing 4 litre glucose/ammonium medium.
In these two weeks, no bacterial growth of the glucose/ammonium medium could be detected.
After this period, a sample of the the glucose/ammonium medium was brought in contact with Arthrobacter M4 bacteria. The medium was able to support growth of these bacteria, equal to a fresh medium.

4.0. Health aspects Polycide

Chemical based water disinfectants creates possibilities that certain non-desirable side effects to man may occur.

A disinfectant can react with (an)organic matter, to form possible toxic by-products.
Another possible effect from disinfection is the formation of bacterial mutants.
Besides these dangers, the disinfectant residual itself may be harmfull.

4.1. Formation of trihalomethanes (THM's):

The most troublesome organics in water treatment are trihalomethanes (THM's) and synthetic organic chemicals. THM's are a by-product of chemical water treatment.
Epidemiological studies are linking THM's with cancer, Gilbert (1986).

Rickabaugh & Kinman (1978) compared the formation of trihalomethanes caused by iodine and chlorine disinfection of Ohio river water.
The only pre-treatment of this river water was pH adjustment. After this treatment halogen doses of 10 ppm were added. For the test results, see table 6.

Table 6: The amount of total trihalomethanes measured in µM, at a temperature of 25° C, 23 to 24 hours aftter adding 10 ppm halogen.

Halogen 10 ppm	pH 7,5	pH 8.0	pH 8,5	pH 9.0
Cl_2	1,168	1,636	1,810	1,954
NH_2Cl	0,001	0,040	0,169	0,036
I^-	0,041	0,064	0,020	0,387
I_2	0,215	0,169	0,147	0,153

4.2. Mutagenic potential, chlorine versus iodine:

With the present knowledge we are able to say that chlorination of water brings the risk of mutants (biologically modified bacteria) into the field of consumers.
The true hazard of these mutants is their ability to survive under normally lethal conditions for these organisms.
In order to meet the international water standard norms, it is clear that a higher dose of chlorine(compounds) is required to inactivate all the micro-organisms.

Chlorine

Maruoka & Yamanaka (1983) used polluted river water from the Katsura river (Japan), which is used as a main source of drinking water for more than ten million citizens. Organic extracts recovered from this water

were mutagenic, as measured by the Ames-test.
Chlorination, with sodium hypochlorite, without pretreatment, 5 mgr./ltr for 20 hours, resulted in an increase in mutagenic activity.
Present results suggest that chlorination produced 'de novo' mutagenic substances and/or increased the mutagenic activity of pre existing mutagenic substances in the river water, caused by a reaction of chlorine with organic components.

Venkochbar et al. (1977) studied the effect of chlorine on cell-membrane functions.
Chlorine was dosed at a level of 1,5 mg/ltr. At this level, chlorine induced leakage of macro-molecules from the cells of Escherchia Coli bacteria. Proteins and RNA were detected in the supernatant. Only at high chlorine doses the present of DNA was observed.

Murray et al. (1984) isolated lactose-fermenting bacteria from raw sewage influent and from chlorinated sewage effluent. After chlorination they found an increase in resistance for some bacteria to one or more antibiotics.
The results indicate that chlorination, while initially lowering the total number of bacteria in sewage, may substantially increase the proportion of antibiotic-resistant potentially patogenic organisms.

Ridgeway & Olson (1982) compared the relative chlorine sensitivity of bacteria from chlorinated and non-chlorinated drinking water distribution systems.
Bacteria from the chlorinated system were more resistant to both the combined and free forms of chlorine than those from the unchlorinated system. They suggest that there may be selection for more chlorine-tolerant micro-organisms in chlorinated water.
The most resistant micro-organisms were able to survive a 2 min. exposure to 10 mg. of free chlorine per litre. Evidence have been reported that sublethal concentrations of chlorine may lead to physiological or genetic selection for increased resistance to this halogen.

Iodine

Fina & Lambert (1975) draw the conclusion that iodine just inactivates vital cytoplasmatic enzymes.

Fina et al. (1982) did not find any effect from iodine on DNA and RNA.

Brandrick & Newton (1967) treated bacteria with free iodine. They found that 90% of the amount of iodine used, appeared as iodide in the solution. They concluded that iodine is not absorbed by the cells.

Alvarez & O'Brien (1982) compared the mechanisms of inactivation of poliovirus by chlorine dioxide and iodine.
They concluded that chlorine dioxide inactivated poliovirus by reacting with the viral RNA and impairing the ability of the viral genome to act as a template for RNA synthesis.
Iodine inactivated viruses by impairing their ability to absorb to HeLa cells. This means that iodine reduces the ability of the virions to absorb to host cells.
No iodine became associated with the viruses. It appears that the most active species of iodine in virus inactivation is the HI0 molecule. They suggest that this HI0 molecule reacts with the protein coat of the virus and not with the RNA. By others iodine has been shown to act on other proteins and viruses by oxidation of sufhydryl groups, which results in little of no binding of the halogen.

Frans Egstorf, who invented Polycide, formulates the theory that iodine does not have the ability to reach the DNA because of its low redox potential.
Its only action is the specific oxidation of sulfohydryl groups within the cell-membrane.
Since these S-H groups are vital for life supporting functions within the living cell, any damage of a sufficient number of these groups is fatal.

4.3. Iodine:

As an essential constituent of thyroid hormone, iodine is an indispensable ingredient of human and animal nutrition. The daily requirements in adults is placed at about 1 to 2 µg per kilogram of body weight. An iodine intake between a minimum of 50 µg and a maximum of 1.000 µg is considered to be safe.
In 1980, the recommended daily allowance (RDA) in the U.S. for iodine was between 40 and 200 µg, depending of age and sex (pregnancy).
Bagchi (1985), notes that the daily intake in the U.S. is two to five times more than this recommended allowance. We could trace no literature indicating that these intake levels result in negative health effects.
In the Netherlands the iodine intake is about 284 µg per person per day.
Suzuki (1985) states that in Japan the intake of iodine ranges from 500 to 3.000 µg per day per capita.

Iodine deficiency

If iodine is not administrated in sufficient quantities, certain ill-effects such as goitre can occur in sensitive persons.
Absolute iodine deficiency is the most common world-wide cause of endemic goitre and cretinism.

At present, more than 200 million people, especially in third-world countries, are affected by endemic iodine deficient goitre. Many countries depent on imports of iodine for their basic needs of iodinized salt administration to the people.

High iodine intake

Endemic goitre can also occur in areas where the population has a massive intake of iodine, in many cases due to a diet of seaweed which is a rich source of iodine.

Suzuki et al. (1965) discovered that in the coastal area of Hokaido (Japan) some persons suffer from endemic goitre, due to very high daily intakes of iodine because of an extremely high consumption of kelp, a kind of seaweed.
Urinary excretion of iodine exeeded sometimes 20.000 µg per day.
The endemic goitrous patients of Hokaido, have an intake of iodine at least three times as large as normal Japanese people and about four hundred to a thousand times more than the goitrous patients in iodine deficient districts.
Susuki (1985) states that, as far as the literature is concerned, 24 cases of sporadic iodide goitre have been documented in Japan, caused by chronic ingestion of large doses of iodide.

Health hazards

EPA or WHO standards for the amount of iodine in drinking water do not exist.
The water supply industry seems to have a concensus that medium to long term use of drinking water containing iodine (0,5-2.0 ppm) is undesirable, because of certain toxicological risks.

A World Health publication by Zoeteman (1972) states that: "it is clear that a prolonged administration of several miligrams 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 pysiological effect on prolonged use over many years, especially in children."
"The possibility arises, although rare, that continued consumption of iodinated water (0,5-1.0 ppm) may have an adverse effect on individuals with impaired thyroid functions or on the unborn child".

Kinman et al (1970) reported: " 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 gallon per day 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."

Suzuki (1985) finds that the more iodine is stored in the thyroid gland, the more iodine in non-hormonal forms leaks out of the thyroid gland.
"Taken together: it seems clear that, in normal man, the thyroid could maintain an adequate hormone balance, despite excess iodide supply, by the processes which include:
1) a decrease in iodide clearance;
2) a transient inhibition of hormonogenesis, followed by an escape from it;
3) an enhancement of non-hormonal iodine leak, and
4) possible inhibition of thyroglobulin proteolysis".
Patients who have a derangement of thyroid, were found to be more sensitive, not only to an acute iodide load but to chronic doses of iodide.
Susuki (1965) found that "In coast goitre patients taking their usual diet rich in seaweed, a significant discharge of iodine by thiocyanate indicates that the thyroid can trap iodide, but fails to convert it into organic iodide". Research outcomes from others showed that iodine in the thyroid was almost exclusively present in the inorganic form.
Thorn & Forsham state that in the biosynthesis of thyroid hormone, iodide or iodine is absorbed in the serum from the gastro intestinal tract, only as inorganic iodide.

5.0. Instructions and conditions of use for Polycide DL 60-50/50, only to be used for drinking water:

Operating instructions:

1) Water to be disinfected shall contain a maximum salt content (as NaCl) of 100 milligrams per litre.

2) The maximum temperature of the water to be disinfected is 40 degrees celcius.

3) One litre of Polycide DL 60-50/50 is able to disinfect 130.000 litres of water, if a pré-filtration with a minimum of 5 μ is used.

4) The pH of the water to be treated should be between pH 4,5 and pH 9.

5) Polycide has to be applied in a plastic column (except PVC), with a relation between length and diameter from 5 : 1 to 7 : 1.

6) The pressure drop caused by the bed-resistance of Polycide is about 0,3 bar per meter of resin.

7) The water to be treated should have a contact-time of at least one minute continuous flow based on the amount of Polycide.

8) At this one minute contact time, the maximum bacteria concentration in the influent water shall be 100.000 bacteria per 100 milliliter of water.

9) The water that has been treated should be consumed within 12 hours.

10) The influent water should not contain active chlorine or compounds that produce active chlorine (organic as wel as in-organic).
    In case active chlorine is present, it can be removed with a pre-treatment with activated-carbon and/or using our second stage "Zerocide" .

11) After arrival of an order of iodine resin from Innorec Research B.V., Polycide has to be rinsed with 10 bedvolumes of water.

12) In case of a stand-still period of 24 hours or more the first bed-volume of water treated with Polycide should not be used for drinking purposes.

13) Polycide will be delivered in submerged form. The design of the water treatment system has to be made in such a way that the iodine resin will stay wet during usage and storage periods.

14) By using a second stage cartridge with "Zerocide", iodine and/or iodide from the effluent water treated with Polycide can be removed.

15) In case the very small amounts of iodine in the effluent water will not be removed (see 14), the following message, in the language of the country, should be printed on the water treatment system:
" The residual iodine should present no principal health hazard to healthy persons. However, pregnant women or persons allergic to iodine and its compounds should consult their physician before use of water treated with Polycide".

Storage and handling instructions:

1) Polycide is stable over a period of at least one year, without degradation of its active material and loss of activity. It has to be stored in submerged form at temperatures above 10 ° celcius and below 45° celcius.

2) Polycide is non poisonous at skin-contact, with exceptance of contact with mucus-membranes or internally taken.

6.0. Conclusions

Test results with Katadyn ceramic filters at DHV's water treatment laboratory showed disinfection outcomes that are not satisfactionary.
These filters were used as a prefiltration step for columns filled with Polycide.
In terms of microbiological quality, after treatment with Polycide, the quality of the effluent water was excellent at a contact time of 15 seconds.
The amount of iodine in the Polycide DL 60-50/50 effluent water was very low, between 10 and 40 μg iodine per litre.
At 130.000 Polycide-bedvolumes of water the test was stopped, while the disinfecting capacity still was outstanding. These results were sufficient to realise an economic feasible application for Polycide in household waterdisinfection units in third world countries.
The bacterial contaminated water used for this testprogram, can be compared with contaminated tapwater one can find in many of these countries.

Results from the research program held at the Department of Microbiology (Agricultural University Wageningen) indicated an extremely low inactivation energy (Ea) for Polycide of 0.554 kcal/mol, compared with chlorine (Ea 12 to 15 kcal/mol) and iodine resins from other manufacturers (19.3 and 29 kcal/mol).
Even at a two seconds contact time, E-coli E 4 concentrations of more than 10^8/ml were completely inactivated.
At these concentrations no iodine in the effluent could be detected.
The iodide residual was measured from 1.5 to 4 x 10^7 I^- ions per inactivated E-coli E 4.

Additional test results with high concentrations of pathogenic bacteria as Salmonella Typhi and Vibrio Cholera El Tor, resulted in complete inactivation.

A two weeks screening test with Polycide for air disinfection resulted in complete absense of viable micro-organisms.

Regarding the formation of trihalomethanes, research outcomes from others indicate that elemental iodine produces 67,8 to 99,5% lower concentrations of TTHM (total trihalomethanes), than chlorine over a pH-range of 7,5 to 9.0 (average reduction of 88%).

Based on our available literature and research results, we propose that iodine, in contrary to chlorine, does not react with the DNA of micro-organisms, and therefore will not cause the direct formation of mutants.

To prevent endemic goitre and cretinism caused by iodine deficiency, a minimum daily iodine intake of 40 μg seems necessary.
According to the DHV testing result, a daily consumption of four litres water, treated with Polycide DL 60-50/50, will result in an extra iodine intake of 80 to160 μg iodine.

Based on the available literature concerning possible health effects from iodine intake, we assume that in areas were the population has an intake of:

1) smaller than 40 µg iodine per day.

   Drinking water treated with Polycide, solves the problem of iodine deficiency.
   More than 200 million persons are now suffering from iodine-deficient goitre.

2) smaller than 800 µg iodine per day.

   No negative health effects may occur from an extra daily intake from 80 to 160 µg iodine.

3) more than 800 µg iodine per day.

   A second stage cartridge with Zerocide can be applied to absorb the amount of iodine and/or iodide from the Polycide effluent water.

According to literature, negative health effects from a chronic iodine intake may occur to the very few persons who have a disturbed thyroid function.

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annex: WHO guidelines for biological and microbiological water quality.

Organism	Unit	Guideline value	Remarks
A Piped water supplies			
A 1 Treated water entering the distribution system			
faecal coliforms	number/100 ml	0	turbidity < 1 NTU, for disinfection with chlorine, pH preferably <8.0, free chlorine residual 0.2-0.5 mg/litre following 30 minutes (minimum) contact
coliform organisms	number/100 ml	0	
A 2 Untreated water entering the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 98% of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number/100 ml	3	in an occasional sample, but not in consecutive samples
A 3 Water in the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 95% of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number/100 ml	3	in an occasional sample but not in consecutive samples
B Unpiped water supplies			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	10	should not occur repeatedly, if occurrence is frequent and if sanitary protection cannot be improved an alternative source must be found if possible
C Bottled drinking-water			
faecal coliforms	number/100 ml	0	source should be free from faecal contamination
coliform organisms	number/100 ml	0	
D. Emergency water supplies			
faecal coliforms	number/100 ml	0	advise public to boil water in case of failure to meet guideline values
coliform organisms	number/100 ml	0	