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Description
Ionene Polymers As Microbicides

This invention relates to methods for the microbicidal control of microorganisms in aqueous systems by treating the system with an effective amount of an ionene polymer. Particularly, it relates to methods for controlling the growth of species (ssp.) within the bacterial genera *Campylobacter*, *Shigella*, *Vibrio* and *Yersinia*, and protozoa within the genus *Entamoeba* in aqueous systems such as potable water, sewage and other nonmarine surface water. This invention also relates to methods for controlling the growth of the bacteria *Mycobacterium bovis*, *Salmonella typhi*, and the fungus *Candida albicans* in these nonmarine aqueous systems. This invention further relates to methods for controlling poliovirus in potable water, sewage, and other nonmarine surface water. Methods for controlling the spread of the diseases cholera and polio are also disclosed.

Cholera is endemic in regions of India and Bangladesh, and has spread to other regions of the globe in a series of pandemics. Recent cholera pandemics from the 1960s through the 1980s have involved Africa, the Philippines, Western Europe and Southeast Asia. In the United States, the number of cases of cholera has increased during the past fifteen years. Zinsser Microbiology 566-73 (W.K. Joklik, H.P. Willett, D.B. Amos, C.A. Wilfert, eds., 20th ed., 1992). Cholera struck recently in Latin America, where the epidemic has affected more than half a million people, resulting in the death of tens of thousands of Latin Americans. The cholera epidemic that currently plagues Latin America began in Peru in 1990, and has spread at least as far as Brazil, Guatemala, Mexico, and Nicaragua. The Pan American Health Organization acknowledged that "once cholera arrives on a continent, it's likely to remain endemic until we make vast improvements in water and sanitation." Christine Tierney, *Central America Suffers Summertime Cholera Surge*, Reuter Newswire, Sept. 4, 1992.

Vibrio cholerae is the species of the bacterial genus *Vibrio*, which causes epidemic cholera, and is among the leading causes of other gastrointestinal infections. *V. parahaemolyticus* is another *Vibrio* that causes gastrointestinal infection, and is prevalent in the United States. Other *Vibrio* ssp. may cause human illnesses that include diarrhea, bloody diarrhea, vomiting, cramps, sepsis and soft tissue infections. For example, *V. vulnificus* may produce infection in a preexisting wound or ulcer, or may cause primary sepsis that may be accompanied by shock that may be fatal. *V. alginolyticus* may also infect wounds, cause middle ear infections (otitis media), or cause bacteremia. S.M. Finegold, W.J. Martin, Diagnostic Microbiology 86-87, 240-46 (6th ed. 1982). *Vibrio* ssp. also cause disease in fishes, eels, frogs, other vertebrates and invertebrates as well. See 1 Bergey's Manual of Systematic Bacteriology 518-38 (N.R. Krieg and J.G. Holt eds. 1984).

Vibrio bacteria are aquatic bacteria distributed throughout the world which often dangerously contaminate aqueous systems and water supplies. Contaminated water supplies pose the most serious source of *Vibrio* infection, as *Vibrio*-associated diseases are transmitted almost exclusively by the fecal contamination of water systems and food materials.

In countries lacking adequate potable water purification facilities, illness is often caused by drinking water contaminated with the bacteria. The drinking of contaminated water is the primary cause of the current cholera pandemics.

In developed countries, *Vibrio*-associated illness is more often caused by the eating of contaminated seafood or shellfish. The contamination results from releasing inadequately treated sewage into the marine environment.

For example, ingestion of raw oysters contaminated with *V. vulnificus* may lead to septicemia in as little as twenty-four hours. Thus, the major defense in the control of

Vibrio-associated illness is the maintenance of adequate water purification and adequate sewage treatment systems. R.Y. Stanier, E.A. Adelberg, J.L. Ingraham, *The Microbial World* 627-29 (1976).

In addition to *Vibrio* bacteria, the methods of control disclosed herein can be used to control the growth of other microorganisms known to possess the potential to cause waterborne diseases. Members of the genus *Campylobacter* are bacteria pathogenic for humans and other mammals. *Campylobacter* is a major cause of diarrhea in adults and children, causing diarrhea as frequently as do *Salmonella* and *Shigella*.

Fever, thrombophlebitis, bacteremia, septic or reactive arthritis, endocarditis, meningoencephalitis, pericarditis, pleuropulmonary infection, cholecystitis, diarrhea and septic abortion may be caused by *C. fetus* subspecies (ss.) *jejuni*, or *C. fetus* ss. *intestinalis* infection. Contaminated water is an important vehicle of infection. S.M. Finegold, W.J. Martin, *Diagnostic Microbiology* 280-81 (6th ed. 1982).

Enteropathogenic *Escherichia coli* are responsible for outbreaks of diarrhea in infants and newborns, and diarrhea, including "traveler's diarrhea", in adults. *E. coli* may be invasive and toxin-producing, causing sometimes fatal infections, such as cystitis, pyelitis, pyelonephritis, appendicitis, peritonitis, gallbladder infection, septicemia, meningitis and endocarditis. Finegold & Martin, at 84-85, 222.

Mycobacterium bovis, like *M. tuberculosis*, *M. africanum*, *M. ulcerans*, and *M. leprae*, is a strict pathogen. *M. bovis* is a significant pathogen throughout much of the world, causing tuberculosis, primarily in cattle. Finegold & Martin, at 351-52.

Opportunistic in nature, *Pseudomonas aeruginosa* may infect burn or wound sites, or the urinary or lower respiratory tracts of immunocompromised hosts. Infection may result in serious septicemia. Finegold & Martin, at 249, 253.

Salmonella spp. cause food poisoning, resulting in nausea, vomiting, diarrhea and sometimes-fatal septicemia. *S. typhi* is the etiological agent of typhoid fever. Finegold & Martin, at 204-06.

Shigella spp., including *S. dysenteriae*, are common waterborne pathogenic agents, causing bacillary dysentery as well as bacteremia and pneumonia. In the United States and Canada, *S. sonnei* and *S. flexneri* have become the most common etiological agents in bacillary dysentery. Finegold & Martin, at 219-221.

Staphylococcus aureus causes one of the most common types of food poisoning. Additionally, various skin infections and more serious diseases, such as toxic shock syndrome, septicemia, meningitis and pneumonia may result from *S. aureus* infection. Finegold & Martin, at 165-66.

Bacteria of the genus *Yersinia* are also pathogens. *Y. enterocolitica* is an enteric pathogen. Infection with this microorganism causes severe diarrhea, gastroenteritis and other types of infections such as bacteremia, peritonitis, cholecystitis, visceral abscesses, and mesenteric lymphadenitis. Septicemia with 50% mortality has been reported. *Y. pestis* is the etiologic agent of bubonic, pneumonic, and septicemic plague in humans. Finegold & Martin, at 230-31.

Candida albicans is a yeast-like fungus that causes acute or subacute infection called candidiasis. The yeast may cause lesions in the mouth, esophagus, genitourinary tract, skin, nails, bronchi, lungs and other organs in immunocompromised hosts. Bloodstream infection, endocarditis, and meningitis caused by *Candida* has been reported. Finegold & Martin, at 429-30.

Entamoeba histolytica is a parasitic amoeba that infects the cecum and large bowel of humans, primates, other mammals and birds. *E. histolytica* may penetrate the epithelial tissues of the colon, causing ulceration symptomatic of amoebic dysentery. The amoeba may spread from the colon to the liver via the portal bloodstream and produce abscesses

(hepatic amebiasis). In a fraction of these cases, the amoebas may spread to other organs, such as lungs, brain, kidney, skin, and frequently be fatal. Stedman's Medical Dictionary 643 (25th ed. 1990). *E. hartmanni* and *E. coli* are more rarely associated with disease in humans. Finegold & Martin, at 497-508.

Giardia intestinalis and *G. lamblia* parasitize the small intestine of many mammals, including man. Infection with *Giardia* (giardiasis) may cause diarrhea, abdominal pain, nausea, anorexia, malaise, fatigue, unexplained eosinophilia, dyspepsia and occasionally malabsorption in humans. Stedman's Medical Dictionary, at 515; Finegold & Martin, at 497, 508-515.

Poliovirus causes acute viral disease (poliomyelitis) sporadically and in epidemics. The disease is endemic in most warm-weather countries throughout the world. Often waterborne, poliovirus may cause minor illness characterized by fever, sore throat, headache, and vomiting, often accompanied by stiffness of the neck and back.

Importantly, poliovirus may cause major illness involving the central nervous system causing paralysis of one or more limbs. Additionally, one form of poliovirus infection (acute bulbar poliomyelitis) affects the brain stem, motor cortex, and medulla oblongata, causing dysfunction of the swallowing mechanism, and respiratory and circulatory distress. Dorland's Illustrated Medical Dictionary 1045 (26th ed. 1981).

This invention provides a method of controlling the above referenced diseases caused by these microorganisms by controlling the growth of these microorganisms in aqueous systems, such as potable water, sewage water, and nonmarine surface water.

An object of this invention is to provide a method for the microbicidal control of unwanted, disease-causing microorganisms in aqueous systems such as potable water, sewage and other nonmarine surface water.

A second object of the invention is to provide methods for controlling microorganisms within the bacterial genera *Campylobacter*, *Shigella*, *Vibrio* and *Yersinia*, and protozoa within the genera *Entamoeba* in aqueous systems such as potable water, sewage and other nonmarine surface water.

A third object of this invention relates to providing a method for controlling the growth of the bacteria *Mycobacterium bovis*, *Salmonella typhi*, and the fungus *Candida albicans* in such aqueous systems.

A fourth object of the invention is to provide a method for controlling poliovirus in aqueous systems such as potable water, sewage, and other nonmarine surface water.

A fifth object is to provide a method for controlling the spread of the diseases caused by the microorganisms discussed above, such as cholera and polio.

Other objects and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention.

To achieve the above objects, and in accordance with the purpose of the invention as embodied and broadly described herein, there are provided:

(1) A method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of the microorganism and in recognized need of such control comprising the step of adding to the aqueous system an ionene polymer in an amount effective to control the growth of at least one microorganism selected from *Campylobacter* spp., *Mycobacterium* spp., *Shigella* spp., *Vibrio* spp., *Yersinia* spp., and *Entamoeba* spp., and wherein the aqueous system is selected from potable water, sewage, and other nonmarine surface water;

(2) A method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of the microorganism and in recognized need of said control comprising the step of adding to the aqueous system an ionene polymer in an amount effective to control the growth of at

least one microorganism selected from *Mycobacterium bovis*, *Salmonella typhi*, and *Candida albicans*, and wherein the aqueous system is selected from potable water, sewage, and other nonmarine surface water;

(3) A method of controlling the spread of cholera transmitted from an aqueous system comprising the step of adding to the aqueous system in recognized need thereof, for the purpose of controlling the spread of cholera, an amount of ionene polymer effective in controlling the growth of *Vibrio* spp., wherein the aqueous system is selected from potable water, sewage, and other nonmarine surface water; and

(4) A method for controlling the spread of polio transmitted from an aqueous system comprising the step of adding to the aqueous system in recognized need thereof, for the purpose of controlling the spread of polio, an amount of ionene polymer effective in controlling the spread of poliovirus, wherein the aqueous system is selected from potable water, sewage, and other nonmarine surface water.

In a first embodiment, the invention relates to a method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of the microorganism where the aqueous system is in recognized need of such control. The method comprises the step of adding to the aqueous system an ionene polymer in an amount effective to control the growth at least one microorganism selected from *Campylobacter* spp., *Mycobacterium* spp., *Shigella* spp., *Vibrio* spp., *Yersinia* spp., and *Entamoeba* spp. The aqueous system may be selected from potable water, sewage, and other nonmarine surface water.

As discussed above, microorganisms selected from *Campylobacter* spp., *Mycobacterium* spp., *Shigella* spp., *Vibrio* spp., *Yersinia* spp., and *Entamoeba* spp. are known to cause diseases in humans as well as other mammals by contaminating the water supply. According to this invention, ionene polymers can be effective in controlling the growth of such microorganisms in aqueous systems and, thus, can be effective in controlling the spread of diseases caused by these

microorganisms. Specifically, ionene polymers are shown below to be effective in the control of *Campylobacter jejuni*, *Mycobacterium bovis*, *Shigella dysenteriae*, *Vibrio cholerae*, *Vibrio parahaemolyticus*, *Yersinia enterocolitica*, and the protozoan *Entamoeba histolytica*.

In the methods of this invention, an ionene polymer is used in an amount effective to accomplish the purpose of the particular method, i.e., to control the growth of at least one microorganism. According to the present invention, control, for example, of the growth or spread of at least one microorganism, means either the inhibition of the growth of a microorganism within the aqueous system or the reduction of the population of a microorganism to an acceptable level. Such control also includes the maintenance of the population of a microorganism in an aqueous system at or below an acceptable level, including zero growth.

The needs of the particular aqueous system determine what amount of ionene polymer will be required to achieve the desired level of control. The concentration of the ionene polymer in a given aqueous system may be, for example, less than or equal to 50 ppm, and preferably less than or equal to 20 ppm. More preferably, the concentration varies from 1 ppm to 10 ppm and most preferably, the ionene polymer is present in the aqueous system at a concentration of approximately 5 ppm.

The methods of the invention are directed to the control of waterborne, disease-causing microorganisms. Thus, the disclosed methods can be employed in any aqueous system which is susceptible to the growth of such microorganisms.

Of particular concern are those aqueous systems that frequently come into contact with humans and other mammals, including livestock, and which can spread the disease-causing microorganism. These aqueous systems include, but are not limited to, potable water, sewage, and other nonmarine surface water such as ponds, lakes, streams, rivers, industrial cooling or contaminant ponds.

A second embodiment of the invention is a method for controlling the growth of at least one microorganism selected from *Mycobacterium bovis*, *Salmonella typhi*, and *Candida albicans* in an aqueous system susceptible to the growth of the microorganism and in recognized need of that control. The method comprises the step of adding to the aqueous system an ionene polymer in an amount effective to control the growth of at least one of those microorganisms. The aqueous system includes those discussed above and preferably is selected from potable water, sewage, and other nonmarine surface water.

The invention also relates to a method of controlling the spread of cholera transmitted from aqueous systems. This method comprises the step of adding to an aqueous system in recognized need thereof, for the purpose of controlling the spread of cholera, an amount of ionene polymer effective in controlling the growth of *Vibrio* species. The aqueous system includes those discussed above. Specifically contemplated are those aqueous systems selected from potable water, sewage, and other nonmarine surface water as discussed above.

To control the spread of polio transmitted from an aqueous system, the invention provides a method comprising the step of adding to the aqueous system in recognized need thereof, for the purpose of controlling the spread of polio, an amount of ionene polymer effective in controlling the spread of poliovirus. The aqueous system may be any of those discussed above and preferably is potable water, sewage, or other nonmarine surface water.

Each of the above methods employs at least one ionene polymer to control the growth of the unwanted, disease causing microorganism in an aqueous system. Ionene polymers or polymeric quaternary ammonium compounds, i.e., cationic polymers containing quaternary nitrogens in the polymer backbone (also known as polymeric quats or polyquats), belong to a well-known class of compounds.

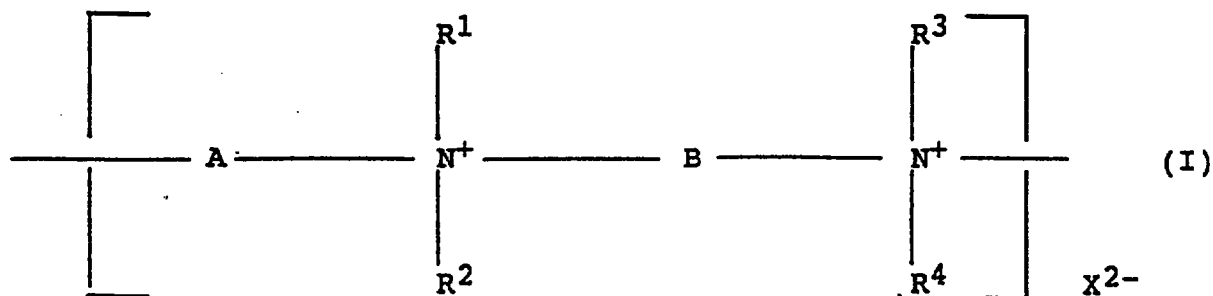
Ionene polymers have been reported to possess biological activity. See, e.g., A. Rembaum, *Biological Activity of Ionene Polymers*, Applied Polymer Symposium No. 22, 299-317 (1973).

Ionene polymers have a variety of uses in aqueous systems such as microbicides, bactericides, algicides, sanitizers, and disinfectants. U.S. Patent Nos. 3,874,870, 3,898,336, 3,931,319, 4,027,020, 4,054,542, 4,089,977, 4,111,679, 4,506,081, 4,581,058, 4,778,813, 4,970,211, 5,051,124, and 5,093,078, the disclosures of all of which are specifically incorporated by reference herein, give various examples of these polymers and their uses.

Ionene polymers have also been used to inhibit surface adhesion of bacteria and algae, U.S. Patent No. 5,128,100, the disclosure of which is specifically incorporated by reference herein. However, ionene polymers have heretofore not been known to be useful for controlling the growth of microorganisms such as *Campylobacter*, *Shigella*, *Vibrio*, *Yersinia*, *Entamoeba* and poliovirus in aqueous systems. It is thus believed that the uses claimed herein for ionene polymers are novel and are not suggested by any heretofore known uses.

Ionene polymers may be classified according to the repeating unit found in the polymer. This repeating unit results from the reactants used to make the ionene polymer.

A first type of ionene polymer comprises the repeating unit of formula I:



In this formula, R^1 , R^2 , R^3 , and R^4 can be identical or different, and are selected from H, C_1 - C_{20} alkyl optionally substituted with at least one hydroxyl group, and benzyl optionally substituted on the benzene moiety with at least one C_1 - C_{20} alkyl group. Preferably, R^1 , R^2 , R^3 and R^4 are all methyl or ethyl.

The group "A" is a divalent radical selected from C_1 - C_{10} alkyl, C_2 - C_{10} alkenyl, C_2 - C_{10} alkynyl, C_1 - C_{10} hydroxyalkyl, symmetric or asymmetric di- C_1 - C_{10} -alkylether, aryl, aryl- C_1 - C_{10} -alkyl, or C_1 - C_{10} -alkylaryl- C_1 - C_{10} alkyl. Preferably, "A" is C_1 - C_5 alkyl, C_2 - C_5 alkenyl, C_2 - C_5 hydroxyalkyl, or symmetric di- C_2 - C_5 -alkylether, and most preferably "A" is propylene, 2-hydroxypropylene or diethyleneether.

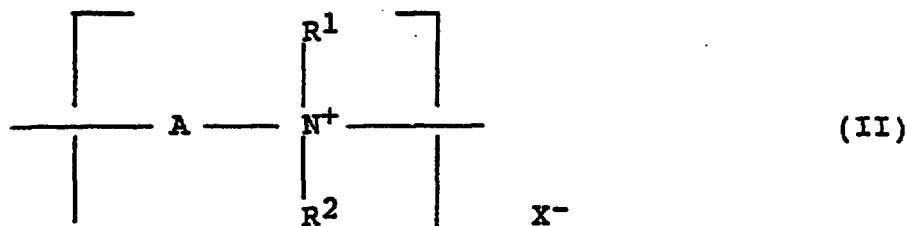
The group "B" is a divalent radical selected from C_1 - C_{10} alkyl, C_2 - C_{10} alkenyl, C_2 - C_{10} alkynyl, C_1 - C_{10} hydroxyalkyl, aryl, aryl- C_1 - C_{10} -alkyl, or C_1 - C_{10} -alkylaryl- C_1 - C_{10} -alkyl. Preferably, "B" is C_1 - C_5 alkyl, C_2 - C_5 alkenyl, C_2 - C_5 hydroxyalkyl, aryl, aryl- C_1 - C_5 -alkyl, or C_1 - C_5 alkylaryl- C_1 - C_5 alkyl. Most preferably "B" is ethylene, propylene, butylene or hexamethylene.

The counter ion, X^{2-} , is a divalent counter ion, two monovalent counter ions or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in the repeating unit which forms the ionene polymer backbone. Preferably, X^{2-} is two monovalent anions selected from a halide anion and a trihalide anion and more preferably, chloride or bromide. Ionene polymers having trihalide counter ions are described in U.S. Patent No. 3,778,476. The disclosure of that patent is incorporated herein by reference.

The ionene polymers having the repeating unit of formula I may be prepared by a number of known methods. One method is to react a diamine of the formula $R^1R^2N-B-NR^1R^2$ with a dihalide of the formula $X-A-X$. Ionene polymers having this repeating unit and methods for their preparation are, for example, described in U.S. Patents Nos. 3,874,870, 3,931,319, 4,025,627, 4,027,020, 4,506,870 and 5,093,078; the

disclosures of which are incorporated herein by reference. The biological activity of ionene polymers having the repeating unit of formula I is also described in these patents.

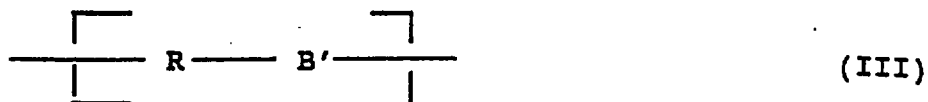
A second type of ionene polymer comprises the repeating unit of formula II:



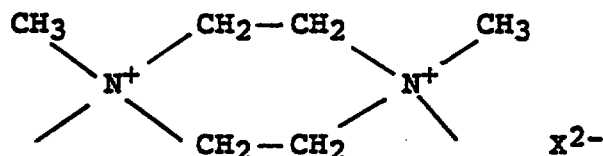
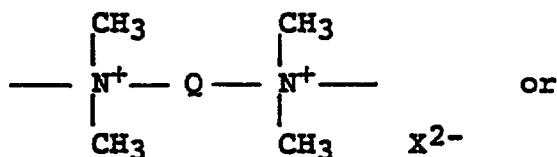
In this formula II, the definitions of R^1 , R^2 , and A are the same as those defined above for formula I. X^- is a monovalent counter ion, one-half of a divalent counter ion or a fraction of a polyvalent counter ion sufficient to balance the cationic charge of the repeating unit which forms the ionene polymer. X^- may be, for example, a halide or trihalide anion and is preferably chloride or bromide.

The ionene polymers having the repeating unit of formula II may be prepared by known methods. One method is to react an amine of the formula $\text{R}^1\text{R}^2\text{N}$ with a haloepoxide such as epichlorohydrin. Ionene polymers having the repeating unit of formula II are, for example, described in U.S. Patents Nos. 4,111,679 and 5,051,124, the disclosures of which are incorporated herein by reference. The biological activity of ionene polymers having the repeating unit of formula II is also described in these patents.

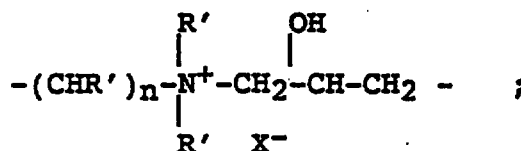
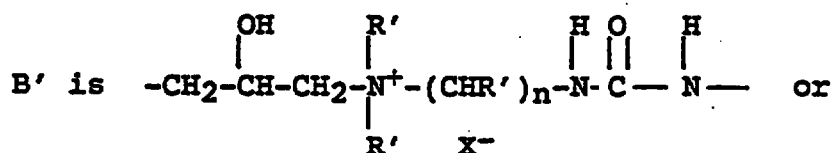
A third type of ionene polymer comprises a repeating unit of formula III:



wherein R is



Q is $-(\text{CHR}')_p-$, $-\text{CH}_2\text{---CH=CH---CH}_2-$, $-\text{CH}_2\text{---CH}_2\text{---O---CH}_2\text{---CH}_2-$, $-\text{CH}_2\text{---CH(OH)---CH}_2-$, or



wherein: n and p independently vary from 2 to 12; each R' is independently hydrogen or a lower alkyl group; X^{2-} is a divalent counter ion, two monovalent counter ions or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in the group R; and X^- is a monovalent counter ion, one-half of a divalent counter ion or a fraction

of a polyvalent counter ion sufficient to balance the cationic charge in the group B'.

Preferably, R' is hydrogen or a C₁-C₄ alkyl; n is 2-6 and p is 2-6. Most preferably, R' is hydrogen or methyl, n is 3 and p is 2. Preferred counter ions, X²⁻ and X⁻ are the same as those discussed above in formulae I and II.

The polymers of formula III are derived from bis(dialkylaminoalkyl) ureas, which are also known as urea diamines, by known methods. Ionene polymers of the formula III, methods of their preparation, and their biological activities are, for example, described in U.S. Patent No. 4,506,081; the disclosure of which is incorporated here by reference.

Ionene polymers comprising the repeating units of formulae I, II, and III may also be cross-linked with primary, secondary or other polyfunctional amines using means known in the art. Ionene polymers can be cross-linked either through the quaternary nitrogen atom or through another functional group attached to the polymer backbone or to a side chain.

Cross-linked ionene polymers, prepared using cross-linking coreactants, are disclosed in U.S. Patent No. 3,738,945 and Reissue U.S. Patent No. 28,808, the disclosures of which are incorporated here by reference. The Reissue Patent describes the cross-linking of ionene polymers prepared by the reaction of dimethylamine and epichlorohydrin. The cross-linking coreactants listed are ammonia, primary amines, alkylenediamines, polyglycolamines, piperazines, heteroaromatic diamines and aromatic diamines.

U.S. Patent No. 5,051,124, the disclosure of which is incorporated herein by reference, describes cross-linked ionene polymers resulting from the reaction of dimethylamine, a polyfunctional amine, and epichlorohydrin. Methods of inhibiting the growth of microorganisms using such cross-linked ionene polymers are also described.

Other examples of various cross-linked ionene polymers and their properties are provided in U.S. Patent Nos. 3,894,946, 3,894,947, 3,930,877, 4,104,161, 4,164,521, 4,147,627, 4,166,041, 4,606,773, and 4,769,155. The disclosures of each of these patents is incorporated herein by reference.

The ionene polymers comprising the repeating units of formulae I, II, or III may also be capped, i.e., have a specific end group. Capping may be achieved by means known in the art. For example, an excess of either reactant used to make the ionene polymer can be employed to provide a capping group. Alternatively, a calculated quantity of a monofunctional tertiary amine or monofunctional substituted or unsubstituted alkyl halide can be reacted with an ionene polymer to obtain a capped ionene polymer. Ionene polymers can be capped at one or both ends. Capped ionene polymers and their microbicidal properties are described in U.S. Patents Nos. 3,931,319 and 5,093,078, the disclosures of each of these patents is incorporated herein by reference.

Among the ionene polymers discussed above, a particularly preferred ionene polymer having a repeating unit of formula I is poly[oxyethylene(dimethyliminio)ethylene(dimethyliminio)ethylene dichloride]. In this ionene polymer, R^1 , R^2 , R^3 and R^4 are each methyl, A is $-\text{CH}_2\text{CH}_2\text{OCH}_2\text{CH}_2-$, B is $-\text{CH}_2\text{CH}_2-$, and X^{2-} is 2Cl^- , and the average molecular weight is 1,000-5,000. This ionene polymer is available from Buckman Laboratories, Inc. of Memphis, Tennessee as Busan® 77 product, a 60% aqueous dispersion of the polymer, or WSCP® product, a 60% aqueous dispersion of the polymer. Busan® 77 and WSCP® are biocides used primarily in aqueous systems, including metalworking fluids for microorganism control.

Another particularly preferred ionene polymer having a repeating unit of formula I, also available from Buckman Laboratories, Inc. as Busan® 79 product, or WSCP II product is the ionene polymer where R^1 , R^2 , R^3 and R^4 are each methyl, A is $-\text{CH}_2\text{CH}(\text{OH})\text{CH}_2-$, B is $-\text{CH}_2\text{CH}_2-$, and X^{2-} is 2Cl^- .

This ionene polymer is a reaction product of N,N,N',N'-tetramethyl-1,2-ethanediamine, with (chloromethyl)-oxirane, and has a 1,000-5,000 average molecular weight. The polymer product Busan® 79 or WSCPII product is a 60% aqueous solution of the polymer.

Preferred ionene polymers having the repeating unit of formula II are those where R¹ and R² are each methyl, A is -CH₂CH(OH)CH₂-, and X⁻ is Cl⁻. Busan® 1055 product is a 50% aqueous dispersion of such an ionene polymer obtained as a reaction product of dimethylamine with (chloromethyl)oxirane having a 2,000-10,000 average molecular weight.

Busan® 1157 product is a 50% aqueous dispersion of the ionene polymer having the repeating unit of formula II, obtained as a reaction product of dimethylamine with epichlorohydrin, cross-linked with ethylenediamine, where R¹ and R² are each methyl, A is -CH₂CH(OH)CH₂- and X⁻ is Cl⁻. This ionene polymer has a 100,000-500,000 average molecular weight.

Busan® 1155 product is a 50% aqueous dispersion of an ionene polymer having the repeating unit of formula II, where R¹ and R² are each methyl, A is -CH₂CH(OH)CH₂-, X⁻ is Cl⁻ and the ionene polymer is cross-linked with ammonia. This ionene polymer has a molecular weight of approximately 100,000-500,000.

Busan® 1099 product or Bubond® 65 product is a 25% aqueous dispersion of a cross-linked ionene polymer having repeating units of formula II, where R¹ and R² are each methyl, A is -CH₂CH(OH)CH₂-, X⁻ is Cl⁻, the cross-linking agent is monomethylamine. This ionene polymer has a molecular weight of approximately 10,000-100,000.

Preferred ionene polymers having the repeating unit of formula III are those where R is a urea diamine and B' is CH₂CH(OH)CH₂, and X⁻ is Cl⁻. BL® 1090 is a 50% aqueous dispersion of the ionene polymer obtained as a reaction product of N,N'-bis-[1-(3-(dimethylamino)-propyl]urea and epichlorohydrin, such an ionene polymer having a 2,000-15,000, preferably 3,000-7,000, average molecular weight.

Each of the above ionene polymers and products identified by trade name is available from Buckman Laboratories, Inc. of Memphis Tennessee.

The invention will be demonstrated by the following examples, which are intended merely to be illustrative of the present invention and are not limiting.

EXAMPLE 1

Ionene polymers were evaluated for their effectiveness in killing *Vibrio cholerae* in two levels of water hardness. The following ionene polymer products were used: Busan® 77, Busan® 79, Busan® 1055, Busan® 1099, and Busan® 1157.

The microbicidal activity of each polymer was tested at AOAC water hardness levels of 300 ppm and 900 ppm which measures calcium and magnesium levels. 300 ppm AOAC corresponds to a level of moderately hard water. 900 ppm indicates extremely hard water, approaching brackishness.

For each ionene polymer product, the following weight/weight concentrations of the ionene polymer product in the test system were used: 0.0 ppm, 5.0 ppm, 10.0 ppm, and 20.0 ppm. *V. cholerae* ATCC # 14035, GBL # 52107, were exposed in aqueous solution supplemented with .01% trypticase soy broth for 24 hours at room temperature. Vibriocide survivors were determined by plate count in alkaline trypticase soy agar. The results, which are summarized in Tables 1 through 5, show that ionene polymers, when used in accordance with the present invention, provide dramatic reductions in the viability of *V. cholerae*, as evidenced by the decrease in surviving bacteria plated after 24 hours exposure. The complete kill, <10 cfu/ml survivors, at concentrations as low as 5.0 ppm ionene polymer product in AOAC hardness 300 ppm, indicates the effectiveness of ionene polymers against *V. cholerae*. The substantial decrease in the level of surviving *V. cholerae* in as little as 20 ppm in 4 out of 5 of the polymers at AOAC 900 ppm illustrates the effectiveness of ionene polymers against *V. cholerae* even in extremely hard water.

TABLE 1

Busan® 77				
Dose Level, ppm	0	5	10	20
Bacterial Count (cfu/ml)				
AOAC 300 ppm	1.4×10^6	<10	<10	<10
AOAC 900 ppm	1.2×10^7	1.2×10^3	9.1×10^2	4.7×10^2

TABLE 2

Busan® 79				
Dose Level, ppm	0	5	10	20
Bacterial Count (cfu/ml)				
AOAC 300 ppm	1.4×10^6	<10	<10	<10
AOAC 900 ppm	1.2×10^7	2.1×10^5	2.3×10^3	70

TABLE 3

Busan® 1055				
Dose Level, ppm	0	5	10	20
Bacterial Count (cfu/ml)				
AOAC 300 ppm	1.4×10^6	<10	<10	<10
AOAC 900 ppm	1.2×10^7	2.0×10^6	1.3×10^5	9.1×10^3

TABLE 4

Busan® 1099				
Dose Level, ppm	0	5	10	20
Bacterial Count (cfu/ml)				
AOAC 300 ppm	1.4×10^6	<10	<10	<10
AOAC 900 ppm	1.2×10^7	6.2×10^5	4.0×10^5	2.5×10^4

TABLE 5

Busan® 1157				
Dose Level, ppm	0	5	10	20
Bacterial Count (cfu/ml)				
AOAC 300 ppm	1.4×10^6	<10	<10	<10
AOAC 900 ppm	1.2×10^7	1.2×10^7	1.5×10^6	3.7×10^6

EXAMPLE 2

Ionene polymer products Bubond® 65, Busan® 77, Busan® 79 and Busan® 1055 were evaluated for effectiveness in killing the bacteria *Campylobacter jejuni*, *Escherichia coli*, *Mycobacterium bovis*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Shigella dysenteriae*, *Staphylococcus aureus*, *Vibrio parahaemolyticus* ATCC 17802, *Yersinia enterocolitica*, and the yeast *Candida albicans*, in deionized water and artificial pond water. Results are shown in Tables 6-9.

Sterile deionized water, pH 7 to 7.5, was supplemented with polymer products at the concentrations of 2.5 ppm, 10 ppm, and 20 ppm.

Artificial pond water consisted of sterile deionized water, sterile salts (350 ppm KCl, 350 ppm CaCl₂, 350 ppm NaCl) and 0.01% sterile trypticase soy broth. Polymer products were added to this medium at concentrations of 5 ppm, 10 ppm, and 20 ppm.

Bacteria, except for *Campylobacter jejuni* and *Mycobacterium Bovis*, and yeast were cultured in trypticase soy broth for 24-36 hours and seeded into 100 ml of the test solution at a concentration of 10^4 cfu/ml. The bacteria and yeast were contacted with the solution for 18-24 hours at 20-25°C without agitation, then quantitated by standard pour plate methodology in trypticase soy agar.

Campylobacter jejuni growth was quantitated by spread plate technique on Chocolate Agar, and incubated at 37°C in a BBL "Campy Pack" for 48 hours. *Mycobacterium bovis* growth

Campylobacter jejuni growth was quantitated by spread plate technique on Chocolate Agar, and incubated at 37°C in a BBL "Campy Pack" for 48 hours. *Mycobacterium bovis* growth was quantitated by membrane filtration and cultivated in Glucose Base broth at 35°C for 28 days.

TABLE 6

Microbicidal Activity of Bubond® 65					
Dose Level, ppm	0	2.5	5	10	20
Bacterial Count (cfu/ml)					
<i>Campylobacter jejuni</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Escherichia coli</i>					
Deionized Water	1.0 x 10 ⁴	5.0 x 10 ³	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	3.0 x 10 ⁴	<10	<10
<i>Pseudomonas aeruginosa</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	210	<10	<10
<i>Salmonella typhi</i>					
Deionized Water	1.0 x 10 ⁴	3.1 x 10 ⁴	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	1.6 x 10 ⁴	<10	<10
<i>Shigella dysenteriae</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Staphylococcus aureus</i>					
Deionized Water	1.0 x 10 ⁶	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Vibrio parahaemolyticus</i>					
Deionized Water	1.0 x 10 ⁶	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	600	470	750
<i>Yersinia enterocolitica</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Mycobacterium bovis</i>					
Deionized Water	28	<1	NT	NT	NT
Artificial Pond Water	28	NT	9	NT	NT
Yeast Count					
<i>Candida albicans</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10

NT = Not tested

TABLE 7

Microbicidal Activity of Busan® 77					
Dose Level, ppm	0	2.5	5	10	20
Bacterial Count (cfu/ml)					
<i>Campylobacter jejuni</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Escherichia coli</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	<10	<10	<10
<i>Pseudomonas aeruginosa</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	810	<10	<10
<i>Salmonella typhi</i>					
Deionized Water	1.0 x 10 ⁴	50	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	620	<10	<10
<i>Shigella dysenteriae</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Staphylococcus aureus</i>					
Deionized Water	1.0 x 10 ⁶	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Vibrio parahaemolyticus</i>					
Deionized Water	1.0 x 10 ⁶	700	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	2.1 x 10 ³	570	<10
<i>Yersinia enterocolitica</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Mycobacterium bovis</i>					
Deionized Water	28	<1	NT	NT	NT
Artificial Pond Water	28	NT	9	NT	NT
Yeast Count					
<i>Candida albicans</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	40	<10	<10

NT = Not tested

TABLE 8

Microbicidal Activity of Busan® 79					
Dose Level, ppm	0	2.5	5	10	20
Bacterial Count (cfu/ml)					
<i>Campylobacter jejuni</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Escherichia coli</i>					
Deionized Water	1.0 x 10 ⁴	2.1 x 10 ⁴	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	<10	<10	<10
<i>Pseudomonas aeruginosa</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	<10	<10	<10
<i>Salmonella typhi</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	<10	<10	<10
<i>Shigella dysenteriae</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Staphylococcus aureus</i>					
Deionized Water	1.0 x 10 ⁶	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Vibrio parahaemolyticus</i>					
Deionized Water	1.0 x 10 ⁶	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	1.05 x 10 ³	450	<10
<i>Yersinia enterocolitica</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Mycobacterium bovis</i>					
Deionized Water	28	5	NT	NT	NT
Artificial Pond Water	28	NT	1	NT	NT
Yeast Count					
<i>Candida albicans</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10

NT = Not tested

TABLE 9

Microbicidal Activity of Busan® 1055					
Dose Level, ppm	0	2.5	5	10	20
Bacterial Count (cfu/ml)					
<i>Campylobacter jejuni</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Escherichia coli</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	<10	<10	<10
<i>Pseudomonas aeruginosa</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	<10	<10	<10
<i>Salmonella typhi</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	<10	<10	<10
<i>Shigella dysenteriae</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Staphylococcus aureus</i>					
Deionized Water	1.0 x 10 ⁶	2.9 x 10 ⁴	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Vibrio parahaemolyticus</i>					
Deionized Water	1.0 x 10 ⁶	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁵	NT	3.1 x 10 ²	<10	<10
<i>Yersinia enterocolitica</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10
<i>Mycobacterium bovis</i>					
Deionized Water	28	NT	NT	NT	<.001
Artificial Pond Water	28	NT	NT	<.001	NT
Yeast Count					
<i>Candida albicans</i>					
Deionized Water	1.0 x 10 ⁴	<10	NT	<10	<10
Artificial Pond Water	1.0 x 10 ⁴	NT	<10	<10	<10

NT = Not tested

EXAMPLE 3

Ionene polymer products Bubond® 65, Busan® 77, Busan® 79 and Busan® 1055 were evaluated for effectiveness in killing the protozoan *Entamoeba histolytica* ATCC 30922 GBL Lab. No. 42409.

Effectiveness of these polymer products was tested in deionized water and artificial pond water as described in Example 2. The concentration of *Entamoeba* trophozoites in the inoculum was 320/ml. *Entamoeba* were enumerated, as shown in Tables 10-13, by direct microscopic observation of motility in a hemocytometer counting chamber at 400x.

TABLE 10

Microbicidal Activity of Bubond® 65					
Dose Level, ppm	0	2.5	5	10	20
Number of Motile Organisms/ml					
<i>Entamoeba histolytica</i>					
Deionized Water	768	<1	NT	<1	<1
Artificial Pond Water	1086	NT	<1	<1	<1

TABLE 11

Microbicidal Activity of Busan® 77					
Dose Level, ppm	0	2.5	5	10	20
Number of Motile Organisms/ml					
<i>Entamoeba histolytica</i>					
Deionized Water	768	<1	NT	<1	<1
Artificial Pond Water	1086	NT	<1	<1	<1

TABLE 12

Microbicidal Activity of Busan® 79					
Dose Level, ppm	0	2.5	5	10	20
Number of Motile Organisms/ml					
<i>Entamoeba histolytica</i>					
Deionized Water	768	<1	NT	<1	<1
Artificial Pond Water	1086	NT	<1	<1	<1

TABLE 13

Microbicidal Activity of Busan® 1055					
Dose Level, ppm	0	2.5	5	10	20
Number of Motile Organisms/ml					
<i>Entamoeba histolytica</i>					
Deionized Water	768	<1	NT	<1	<1
Artificial Pond Water	1086	NT	<1	<1	<1

The concentration (ppm of the ionene polymer product in the test system) of Bubond® 65, Busan® 77, Busan® 79 and Busan® 1055 required to kill at least 99.9% of the tested pathogenic microorganisms is summarized in Tables 14-17.

TABLE 14

Microorganism	Concentrations (ppm)	
	Deionized Water	Artificial Pond Water
Bacteria:		
<i>Campylobacter jejuni</i>	2.5	5
<i>Escherichia coli</i>	10	10
<i>Mycobacterium bovis</i>	2.5	5
<i>Pseudomonas aeruginosa</i>	2.5	5
<i>Salmonella typhi</i>	10	10
<i>Shigella dysenteriae</i>	2.5	5
<i>Staphylococcus aureus</i>	2.5	5
<i>Vibrio parahaemolyticus</i>	2.5	5
<i>Yersinia enterocolitica</i>	2.5	5
Yeast:		
<i>Candida albicans</i>	2.5	5
Protozoa (trophozoites):		
<i>Entamoeba histolytica</i>	2.5	5

TABLE 15

Microbicidal Activity of Busan® 77		
<u>Microorganism</u>	Concentrations (ppm)	
	<u>Deionized Water</u>	<u>Artificial Pond Water</u>
Bacteria:		
<i>Campylobacter jejuni</i>	2.5	5
<i>Escherichia coli</i>	2.5	5
<i>Mycobacterium bovis</i>	2.5	5
<i>Pseudomonas aeruginosa</i>	2.5	5
<i>Salmonella typhi</i>	2.5	5
<i>Shigella dysenteriae</i>	2.5	5
<i>Staphylococcus aureus</i>	2.5	5
<i>Vibrio parahaemolyticus</i>	2.5	10
<i>Yersinia enterocolitica</i>	2.5	5
Yeast:		
<i>Candida albicans</i>	2.5	5
Protozoa (trophozoites):		
<i>Entamoeba histolytica</i>	2.5	5

TABLE 16

Microbicidal Activity of Busan® 79		
<u>Microorganism</u>	Concentrations (ppm)	
	<u>Deionized Water</u>	<u>Artificial Pond Water</u>
Bacteria:		
<i>Campylobacter jejuni</i>	2.5	5
<i>Escherichia coli</i>	10	5
<i>Mycobacterium bovis</i>	10	5
<i>Pseudomonas aeruginosa</i>	2.5	5
<i>Salmonella typhi</i>	2.5	5
<i>Shigella dysenteriae</i>	2.5	5
<i>Staphylococcus aureus</i>	2.5	5
<i>Vibrio parahaemolyticus</i>	2.5	10
<i>Yersinia enterocolitica</i>	2.5	5
Yeast:		
<i>Candida albicans</i>	2.5	5
Protozoa (trophozoites):		
<i>Entamoeba histolytica</i>	2.5	5

TABLE 17

Microbicidal Activity of Busan® 1055		
Microorganism	Concentrations (ppm)	
	Deionized Water	Artificial Pond Water
Bacteria:		
<i>Campylobacter jejuni</i>	2.5	5
<i>Escherichia coli</i>	2.5	5
<i>Mycobacterium bovis</i>	2.5	5
<i>Pseudomonas aeruginosa</i>	2.5	5
<i>Salmonella typhi</i>	2.5	5
<i>Shigella dysenteriae</i>	2.5	5
<i>Staphylococcus aureus</i>	10	5
<i>Vibrio parahaemolyticus</i>	2.5	10
<i>Yersinia enterocolitica</i>	2.5	5
Yeast:		
<i>Candida albicans</i>	2.5	5
Protozoa (trophozoites):		
<i>Entamoeba histolytica</i>	2.5	5

EXAMPLE 4

Ionene polymer products Bubond® 65, Busan® 77, Busan® 79 and Busan® 1055, were evaluated for effectiveness against poliovirus. 0.3 ml of poliovirus Type 1, maintained as a stock solution (of greater than or equal to 10^6 TC ID₅₀) in EMEM containing 5% calf serum was added to 100 ml of the test solutions described in Example 2. Virus viability was quantitated by calculation of the TC ID₅₀, (the average of one Tissue Culture Infectious Dose for 50% of the test units.) The virus (0.1 ml per well) was cultivated in Hep-2 cells for 5 days at 37°C, 8-10% CO₂. Virus growth, as shown in Tables 18-21, was established by microscopic observation of cytopathic effect to the cell monolayer.

TABLE 18

Microbicidal Activity of Bubond® 65 Against Poliovirus					
Dose Level, ppm	0	2.5	5	10	20
TC ID ₅₀					
Deionized Water	10 ^{5.5}	10 ^{4.7}	NT	10 ^{4.5}	10 ^{5.3}
Artificial Pond Water	10 ^{4.0}	NT	10 ^{4.3}	10 ^{4.5}	10 ^{4.0}

TABLE 19

Microbicidal Activity of Busan® 77 Against Poliovirus					
Dose Level, ppm	0	2.5	5	10	20
TC ID ₅₀					
Deionized Water	10 ^{5.5}	10 ^{3.7}	NT	10 ^{4.7}	10 ^{5.3}
Artificial Pond Water	10 ^{4.0}	NT	10 ^{3.7}	10 ^{4.5}	10 ^{4.0}

TABLE 20

Microbicidal Activity of Busan® 79 Against Poliovirus					
Dose Level, ppm	0	2.5	5	10	20
TC ID ₅₀					
Deionized Water	10 ^{5.5}	10 ^{4.5}	NT	10 ^{4.5}	10 ^{4.3}
Artificial Pond Water	10 ^{4.0}	NT	10 ^{4.0}	10 ^{4.3}	10 ^{4.3}

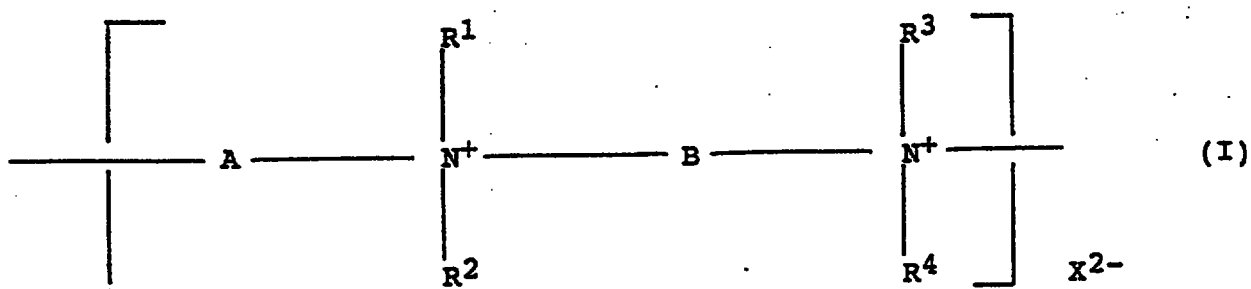
TABLE 21

Microbicidal Activity of Busan® 1055 Against Poliovirus					
Dose Level, ppm	0	2.5	5	10	20
TC ID ₅₀					
Deionized Water	10 ^{5.5}	10 ^{5.3}	NT	10 ^{3.7}	10 ^{4.7}
Artificial Pond Water	10 ^{4.0}	NT	10 ^{5.7}	10 ^{4.7}	10 ^{3.7}

The invention claimed is:

1. A method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of said microorganism and in recognized need of said control comprising the step of adding to said aqueous system an ionene polymer in an amount effective to control the growth at least one microorganism selected from *Campylobacter* spp., *Mycobacterium* spp., *Shigella* spp., *Vibrio* spp., *Yersinia* spp., *Entamoeba* spp., and wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water.

2. A method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of said microorganism and in recognized need of said control comprising the step of adding to said aqueous system an ionene polymer in an amount effective to control the growth at least one microorganism selected from *Campylobacter* spp., *Mycobacterium* spp., *Shigella* spp., *Vibrio* spp., *Yersinia* spp., *Entamoeba* spp., and wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water and said ionene polymer comprises a repeating unit of the formula I:



wherein R¹, R², R³, and R⁴ can be identical or different, and are selected from H, C₁-C₂₀ alkyl optionally substituted with at least one hydroxyl group, and benzyl optionally substituted on the benzene moiety with at least one C₁-C₂₀ alkyl group;



A is a divalent radical selected from C_1 - C_{10} alkyl, C_2 - C_{10} alkenyl, C_2 - C_{10} alkynyl, C_1 - C_{10} hydroxyalkyl, symmetric or asymmetric di- C_1 - C_{10} -alkylether, aryl, aryl- C_1 - C_{10} -alkyl, or C_1 - C_{10} -alkylaryl- C_1 - C_{10} -alkyl;

B is a divalent radical selected from C_1 - C_{10} alkyl, C_2 - C_{10} alkenyl, C_2 - C_{10} alkynyl, C_1 - C_{10} hydroxyalkyl, aryl, aryl- C_1 - C_{10} -alkyl, or C_1 - C_{10} -alkylaryl- C_1 - C_{10} -alkyl; and

X^{2-} is a divalent counter ion, two monovalent counter ions or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in the repeating unit of said ionene polymer.

3. The method of claim 2, wherein R^1 , R^2 , R^3 , and R^4 are methyl or ethyl; A is C_1 - C_5 alkyl, C_2 - C_5 alkenyl, C_2 - C_5 hydroxyalkyl, or symmetric di- C_2 - C_5 -alkylether; B is C_1 - C_5 alkyl, C_2 - C_5 alkenyl, C_2 - C_5 hydroxyalkyl, aryl, aryl- C_1 - C_5 -alkyl, or C_1 - C_5 alkylaryl- C_1 - C_5 -alkyl; and X^{2-} is two monovalent anions each selected from a halide anion or a trihalide anion.

4. The method of claim 3, wherein A is propylene, 2-hydroxypropylene or diethyleneether; B is ethylene or propylene; and X^{2-} is $2Cl^-$.

5. The method of claim 4, wherein R^1 , R^2 , R^3 , and R^4 are $-CH_3$; B is $-CH_2CH_2-$; and A is $-CH_2CH(OH)CH_2-$.

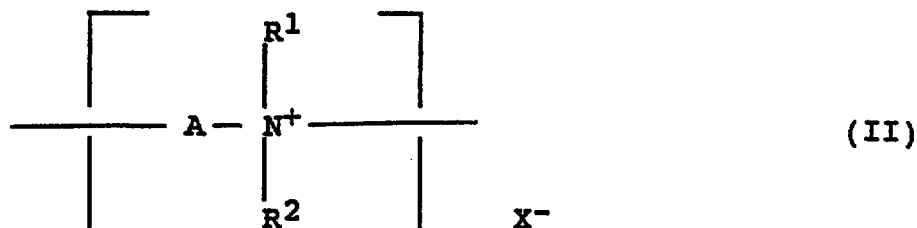
6. The method of claim 4, wherein R^1 , R^2 , R^3 and R^4 are each methyl, A is $-CH_2CH_2OCH_2CH_2-$ and B is $-CH_2CH_2-$.

7. The method of claim 2, wherein said ionene polymer is a cross-linked polymer.

8. A method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of said microorganism and in recognized need of said control comprising the step of adding to said aqueous system an ionene polymer in an amount effective to control the growth at least one microorganism selected from *Campylobacter* spp., *Mycobacterium* spp., *Shigella* spp., *Vibrio* spp., *Yersinia* spp., *Entamoeba* spp., and wherein said aqueous system is



selected from potable water, sewage, and other nonmarine surface water and said ionene polymer comprises a repeating unit of formula II:



wherein R^1 and R^2 can be identical or different, and are selected from H, $\text{C}_1\text{-C}_{20}$ alkyl optionally substituted with at least one hydroxyl group, and benzyl optionally substituted on the benzene moiety with at least one $\text{C}_2\text{-C}_{20}$ alkyl group;

A is a divalent radical selected from $\text{C}_1\text{-C}_{10}$ alkyl, $\text{C}_2\text{-C}_{10}$ alkenyl, $\text{C}_2\text{-C}_{10}$ alkynyl, $\text{C}_1\text{-C}_{10}$ hydroxyalkyl, symmetric or asymmetric di- $\text{C}_1\text{-C}_{10}$ -alkylether, aryl, aryl- $\text{C}_1\text{-C}_{10}$ -alkyl, or $\text{C}_1\text{-C}_{10}$ -alkylaryl- $\text{C}_1\text{-C}_{10}$ -alkyl; and

X^- is a monovalent counter ion, one-half of a divalent counter ion or a fraction of a polyvalent counter ion sufficient to balance the cationic charge of the repeating unit in said ionene polymer.

9. The method of claim 8, wherein R^1 and R^2 may be the same or different and are methyl or ethyl; A is $\text{C}_1\text{-C}_5$ alkyl, $\text{C}_2\text{-C}_5$ alkenyl, $\text{C}_2\text{-C}_5$ hydroxyalkyl, or symmetric di- $\text{C}_2\text{-C}_5$ -alkylether; and X^- is a halide anion.

10. The method of claim 9, wherein A is propylene, 2-hydroxypropylene, or diethyleneether; and X^- is Cl^- .

11. The method of claim 9, wherein R^1 and R^2 are each methyl, and A is $-\text{CH}_2\text{CH}(\text{OH})\text{CH}_2-$.

12. The method of claim 9, wherein R^1 and R^2 are each methyl, and A is $-\text{CH}_2\text{CH}(\text{OH})\text{CH}_2-$ and said ionene polymer is cross-linked with ethylenediamine.

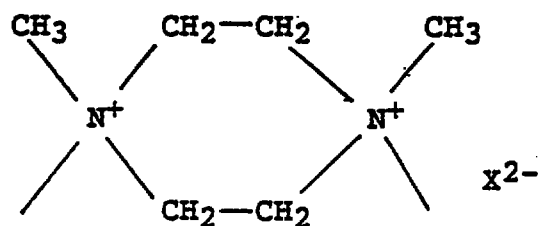
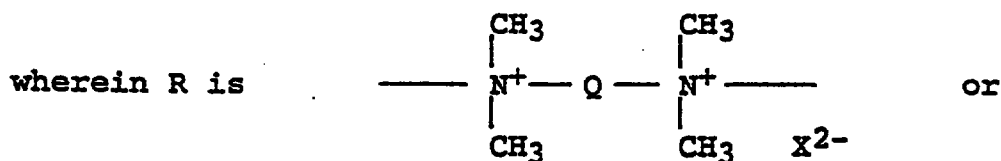
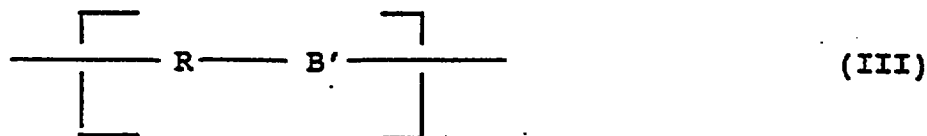
13. The method of claim 9, wherein R^1 and R^2 are each methyl, A is $-\text{CH}_2\text{CH}(\text{OH})\text{CH}_2-$ and said ionene polymer is cross-linked with ammonia.



14. The method of claim 9, wherein said ionene polymer is a 1,1'-(methyliminio)bis(3-chloro-2-propanol) polymer cross-linked with N,N,N',N'-tetramethyl-1,2-ethanediamine.

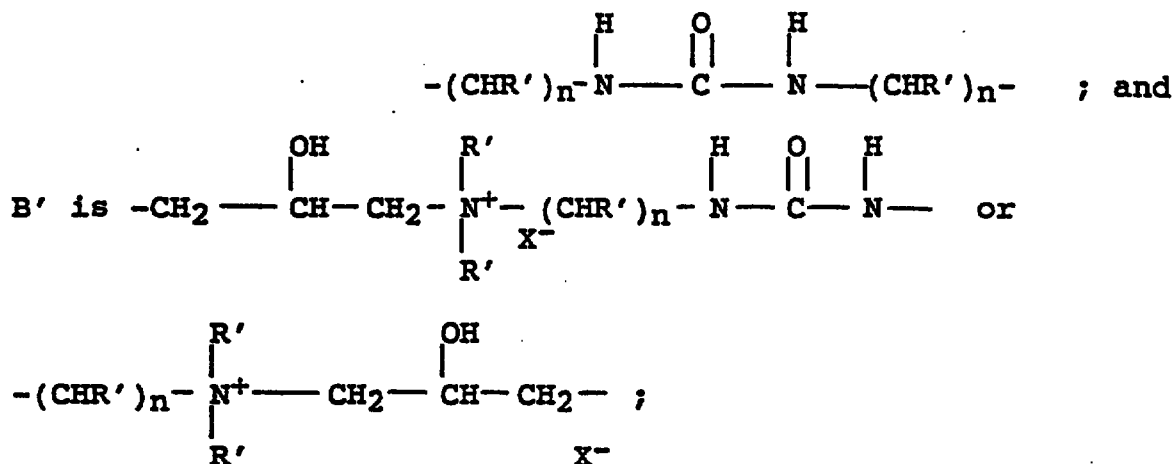
15. The method of claim 9, wherein said ionene polymer is a cross-linked polymer.

16. A method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of said microorganism and in recognized need of said control comprising the step of adding to said aqueous system an ionene polymer in an amount effective to control the growth at least one microorganism selected from *Campylobacter* spp., *Mycobacterium* spp., *Shigella* spp., *Vibrio* spp., *Yersinia* spp., *Entamoeba* spp., and wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water and said ionene polymer comprises a repeating unit of formula III:



Q is $-(\text{CHR}')_p-$, $-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-$, $-\text{CH}_2-\text{CH}_2-\text{O}-\text{CH}_2-\text{CH}_2-$, $-\text{CH}_2-\text{CH}(\text{OH})-\text{CH}_2-$, or





wherein n and p independently vary from 2 to 12; each R' is independently hydrogen or a lower alkyl group; X²⁻ is a divalent counter ion, two monovalent counter ions or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in said group R; and X⁻ is a monovalent counter ion, one-half of a divalent counter ion or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in said group B'.

17. The method of claim 16, wherein R' is hydrogen or C₁-C₄ alkyl, n is 2-6, and p is 2-6.

18. The method of claim 16, wherein R' is hydrogen or methyl, n is 3 and p is 2.

19. The method of claim 16, wherein said ionene polymer is a reaction product of N,N'-bis-[1-(3-(dimethylamino)-propyl)]urea and epichlorohydrin.

20. The method of claim 16, wherein said ionene polymer is a cross-linked polymer.

21. The method of claim 1, wherein said microorganisms are species of *Vibrio* bacteria.

22. The method of claim 21, wherein said *Vibrio* bacteria is *Vibrio cholerae*.

23. The method of claim 21, wherein said *Vibrio* bacteria is *Vibrio parahaemolyticus*.

24. The method of claim 1, wherein said microorganism is *Campylobacter jejuni*.



25. The method of claim 1, wherein said microorganism is *Shigella dysenteriae*.

26. The method of claim 1, wherein said microorganism is *Yersinia enterocolitica*.

27. The method of claim 1, wherein said microorganism is *Entamoeba histolytica*.

28. The method of claim 1, wherein said microorganism is poliovirus.

29. The method of claim 1, wherein said aqueous system is potable water.

30. The method of claim 29, wherein the concentration of said ionene polymer in said potable water is 5 ppm.

31. The method of claim 1, wherein said aqueous system is sewage.

32. The method of claim 1, wherein said aqueous system is nonmarine surface water.

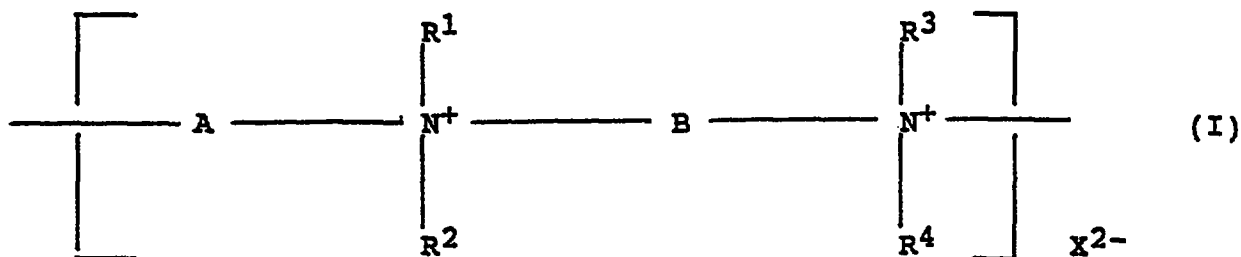
33. A method for controlling the growth of at least one microorganism in an aqueous system susceptible to the growth of said microorganism and in recognized need of said control comprising the step of adding to said aqueous system an ionene polymer in an amount effective to control the growth of at least one microorganism selected from *Mycobacterium bovis*, *Salmonella typhi*, and *Candida albicans*, and wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water.

34. A method of controlling the spread of cholera transmitted from an aqueous system comprising the step of adding to said aqueous system in recognized need of said control, for the purpose of controlling the spread of cholera, an amount of ionene polymer effective in controlling the growth of *Vibrio* species, wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water.

35. A method of controlling the spread of cholera transmitted from an aqueous system comprising the step of adding to said aqueous system in recognized need thereof, for



the purpose of controlling the spread of cholera, an amount of ionene polymer effective in controlling the growth of *Vibrio* species, wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water and said ionene polymer comprises a repeating unit of the formula I:



wherein R^1 , R^2 , R^3 , and R^4 can be identical or different, and are selected from H, $\text{C}_1\text{-C}_{20}$ alkyl optionally substituted with at least one hydroxyl group, and benzyl optionally substituted on the benzene moiety with at least one $\text{C}_2\text{-C}_{20}$ alkyl group;

A is a divalent radical selected from $\text{C}_1\text{-C}_{10}$ alkyl, $\text{C}_2\text{-C}_{10}$ alkenyl, $\text{C}_2\text{-C}_{10}$ alkynyl, $\text{C}_1\text{-C}_{10}$ hydroxyalkyl, symmetric or asymmetric di- $\text{C}_1\text{-C}_{10}$ -alkylether, aryl, aryl- $\text{C}_1\text{-C}_{10}$ -alkyl, or $\text{C}_1\text{-C}_{10}$ -alkylaryl- $\text{C}_1\text{-C}_{10}$ -alkyl;

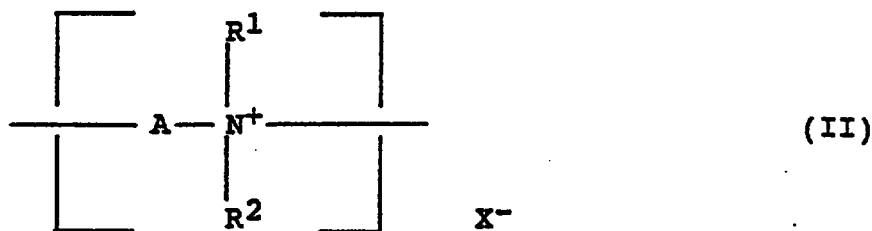
B is a divalent radical selected from $\text{C}_1\text{-C}_{10}$ alkyl, $\text{C}_2\text{-C}_{10}$ alkenyl, $\text{C}_2\text{-C}_{10}$ alkynyl, $\text{C}_1\text{-C}_{10}$ hydroxyalkyl, aryl, aryl- $\text{C}_1\text{-C}_{10}$ -alkyl, or $\text{C}_1\text{-C}_{10}$ -alkylaryl- $\text{C}_1\text{-C}_{10}$ -alkyl; and

X^{2-} is a divalent counter ion, two monovalent counter ions or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in the repeating unit of said ionene polymer.

36. The method of claim 35, wherein R^1 , R^2 , R^3 , and R^4 are methyl or ethyl; A is $\text{C}_1\text{-C}_5$ alkyl, $\text{C}_2\text{-C}_5$ alkenyl, $\text{C}_2\text{-C}_5$ hydroxyalkyl, or symmetric di- $\text{C}_2\text{-C}_5$ alkylether; B is $\text{C}_1\text{-C}_5$ alkyl, $\text{C}_2\text{-C}_5$ alkenyl, $\text{C}_2\text{-C}_5$ hydroxyalkyl, aryl, aryl- $\text{C}_1\text{-C}_5$ alkyl, or $\text{C}_1\text{-C}_5$ alkylaryl- $\text{C}_1\text{-C}_5$ alkyl; and X^{2-} is two monovalent anions each selected from a halide anion or a trihalide anion.



37. A method of controlling the spread of cholera transmitted from an aqueous system comprising the step of adding to said aqueous system in recognized need thereof, for the purpose of controlling the spread of cholera, an amount of ionene polymer effective in controlling the growth of *Vibrio* species, wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water and said ionene polymer comprises a repeating unit of formula II:



wherein R^1 and R^2 can be identical or different, and are selected from H, $\text{C}_1\text{-C}_{20}$ alkyl optionally substituted with at least one hydroxyl group, and benzyl optionally substituted on the benzene moiety with at least one $\text{C}_2\text{-C}_{20}$ alkyl group;

A is a divalent radical selected from $\text{C}_1\text{-C}_{10}$ alkyl, $\text{C}_2\text{-C}_{10}$ alkenyl, $\text{C}_2\text{-C}_{10}$ alkynyl, $\text{C}_1\text{-C}_{10}$ hydroxyalkyl, symmetric or asymmetric di- $\text{C}_1\text{-C}_{10}$ -alkylether, aryl, aryl- $\text{C}_1\text{-C}_{10}$ -alkyl, or $\text{C}_1\text{-C}_{10}$ -alkylaryl- $\text{C}_1\text{-C}_{10}$ -alkyl; and

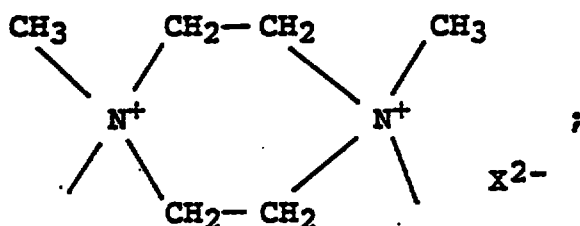
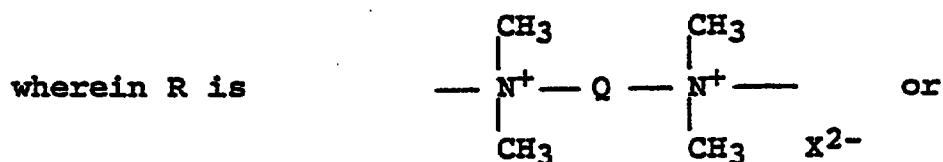
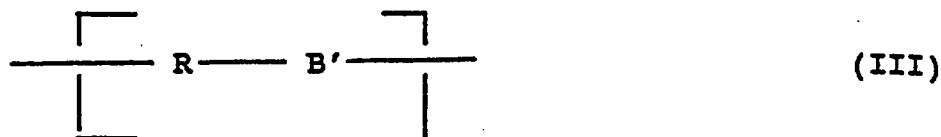
X^- is a monovalent counter ion, one-half of a divalent counter ion or a fraction of a polyvalent counter ion sufficient to balance the cationic charge of the repeating unit in said ionene polymer.

38. The method of claim 37, wherein R^1 and R^2 are methyl or ethyl; A is $\text{C}_1\text{-C}_5$ alkyl, $\text{C}_2\text{-C}_5$ alkenyl, $\text{C}_2\text{-C}_5$ hydroxyalkyl, or symmetric di- $\text{C}_2\text{-C}_5$ -alkylether; and X^- is a halide anion.

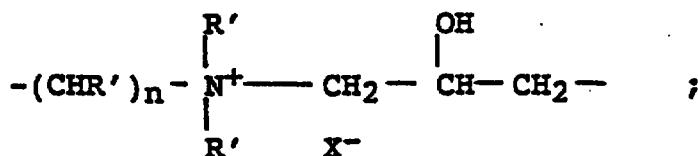
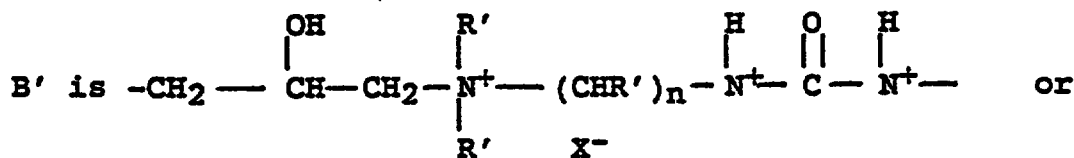
39. A method of controlling the spread of cholera transmitted from an aqueous system comprising the step of adding to said aqueous system in recognized need thereof, for the purpose of controlling the spread of cholera, an amount of ionene polymer effective in controlling the growth of



Vibrio species, wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water and said ionene polymer comprises a repeating unit of formula III:



Q is $-(\text{CHR}')_p-$, $-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-$, $-\text{CH}_2-\text{CH}_2-\text{O}-\text{CH}_2-\text{CH}_2-$, $-\text{CH}_2-\text{CH}(\text{OH})-\text{CH}_2-$, or



wherein n and p independently vary from 2 to 12; each R' is independently hydrogen or a lower alkyl group; x^{2-} is a divalent counter ion, two monovalent counter ions or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in said group R; and X^- is a monovalent



counter ion, one-half of a divalent counter ion or a fraction of a polyvalent counter ion sufficient to balance the cationic charge in said group B'.

40. A method for controlling the spread of polio transmitted from an aqueous system comprising the step of adding to said aqueous system in recognized need thereof, for the purpose of controlling the spread of polio, an amount of ionene polymer effective in controlling the growth of poliovirus, wherein said aqueous system is selected from potable water, sewage, and other nonmarine surface water.

