Environmental Impact Assessment for the Use of Formalin in the Control of External Parasites on Fish

January 1995

Proposed Use of Formalin

Formalin, an aqueous solution of formaldehyde gas, containing not less than 37% by weight of formaldehyde gas per weight of water and 6-13% (12%) methanol, is recommended for the control and prevention of external protozoan parasites on fish. Formalin solution is recommended for use at a concentration of 250 ppm for a contact period of up to one hour for the control of external parasites on fish. Formalin controls the protozoan parasites: Ichthyophthirius spp., Costia spp., Epistylis spp., Chilodonella spp., Scyphidia sp., Trichodina spp.; monogenetic trematodes, including Cleidodiscus spp., Gyrodaclgyrus spp. and Dactylogyrus spp. The treatment should not be used when the water temperature is above 27°C or when the dissolved oxygen drops below 3 to 4 mg/L. The contents of the treatment tanks must be diluted in such a fashion that the formaldehyde concentration in the mixing zone of the receiving waters does not exceed 1 ppm to avoid damage to formaldehyde-sensitive aquatic species.

Chemical and Physical Properties of Formalin

1. Usually a 37-40% solution, by weight, with 10-15% added methanol which prevents polymerization and the formation of paraldehyde, which is toxic to fish.
2. Molecular Weight of Formaldehyde, 30.03. Contains 30.99% C; 6.73% H; and 53.29% O.
3. Solubility- miscible with water, alcohol, acetone.
4. pH of Solution: 2.8-4.0
5. $d_{25/25}$ 1.081-1.085
6. n^{20} 1.3746
7. Boiling Point $_{760\ mm}$ 96°C
8. Flash Point 60°C

Common Chemical Environmental Reactions of Formaldehyde

$$\underset{\text{Formaldehyde}}{H_2C{=}O} + \underset{\text{water}}{H_2O} \longrightarrow \underset{\text{Formalin or Formaldehyde hydrate}}{H_2C\text{-}(OH)_2}$$

$$\underset{\text{Formaldehyde}}{2H_2C{=}O} + \underset{\text{oxygen}}{O_2} \longrightarrow \underset{\text{Formic Acid}}{2\ HCOOH}$$

$$\underset{\text{Formic acid}}{HCOOH} + \underset{\text{oxygen}}{O_2} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O}$$

After application of the formaldehyde gas to the water containing 10 to 15% methanol, formaldehyde hydrate or formalin is formed. The formalin or formaldehyde will undergo oxidation to formic acid which will undergo metabolic oxidation by microorganisms to form carbon dioxide and water. The reactions of the active ingredients indicate the eventual impact on the environment will be minimal, since the active ingredients will be mineralized to carbon dioxide and water. The environmental concern is the immediate toxic effects of formaldehyde upon sensitive aquatic species.

Introduction into the Environment

Formalin is to be used for the control of external protozoan parasites such as Ichthyophthirius spp., Costia spp., Chilodonella spp., Epistylis spp., Scyphidia spp., Trichodina spp.; monogenetic trematodes such as Cleidodiscus spp., Gyrodactylus spp., and Dactylogyrus spp. at a concentration no greater than 250 ppm formalin for no more than one hour. The treatment water should be discharged in such a manner that the concentration in the mixing zone of the receiving water is no greater than 1.0 ppm to avoid damage to sensitive aquatic species.

The following concentration of formalin is recommended for the control of external parasites on fish.

Concentration of Formalin (ppm)

Tanks and Raceways (up to one hour)	Earthen Ponds (indefinitely)
up to 250	15-25[1]

[1]Use the lower concentration when the pond is heavily loaded with fish or phytoplankton.

Methods of Application

Tanks and Raceways - After the water supply has been turned off, apply the appropriate amount of formalin, assuring equal distribution. Provide aeration to the tank or raceway. Allow for a contact or treatment time of up to one hour. Drain the tank or raceway and refill with fresh, well-aerated water. If needed, aeration should be provided to preclude oxygen depletion. Treatment in tanks should not exceed 1 hour, even if fish show no sign of distress.

Ponds - The greatly diluted formalin is applied to the pond using a pump, sprayer, boat bailer or other devices to assure an even distribution. The treatment is allowed to dissipate naturally. Single treatments usually control most parasites, but treatment should be repeated in five to ten days, if needed. If the infective agent is Ichthyophthirius sp., repeat treatments should occur at two-day intervals until control is achieved.

In normal practice, formalin would be added to the ponds at an initial concentration of 15-25 ppm; the concentration declines within 30-36 h. The flow through the ponds would be minimal until the formalin is dissipated. At worst, there would be a minimal discharge of formalin to a stream; at best this form of treatment allows a normal dissipation of the formalin (half-life 36 h).

Discharge of Treatment Water

It is recommended that the contents of treatment tanks or raceways be discharged such that the concentration, as diluted into the stream, should be no greater than 1 ppm.

Assessment of Impact of Formalin in the Environment

The rate of discharge of the formalin-containing treatment water, is a function of the size of the treatment tank or raceway and the receiving body of water.

For the purpose of this assessment, the following assumptions will be made:

1. The model treatment tank/raceway used for this assessment will have a dimension of 50 ft. long x 10 ft. wide x 2 ft. deep and have a volume of 1000 $ft.^3$ or 7,480 gallons.
2. The water in the tank will be exchanged essentially completely after the treatment period and the water completely replaced.
3. The concentration in the treatment tank will be 250 ppm, the maximum use treatment level for parasite infected fish.
4. Unlike the pond systems of growing fish, in the treatment tank or raceway there will be no dissipation of the formalin because of the short time period associated with the treatment period, one hour.
5. The half-life of formalin in water is estimated at 36 hr.

Calculation of Case Situations

Case Situation 1

Assume the disposal would be a direct discharge into an adjacent stream that is 20 ft wide with an average depth of 4 ft and a flow of 2 ft/second. This size stream is not considered excessive, since most fish hatcheries need a stream or water source of significant size to obtain sufficient water for operation without impairing the flow the stream significantly. If the volume of the treatment tank/raceway was 50 ft x 10 ft x 2 ft, the tank/raceway would have a volume of 1000 ft^3 or 7,480 gallons. If the contents of the tank/raceway were pumped directly into a stream using a pump with a capacity of 600 gallon/min (a velocity well within the realm of pumps in most fish hatcheries), 12.46 min would be required to empty the tank and have the tank refilled with fresh stream water. Assuming minimal diffusion between the replacement water and the formalin-containing treatment water, the flow from the treatment tank would be diluted giving the following concentration:

600 gallons/minute pump flow x 250 ppm formalin ÷ [20 ft wide stream x 4 ft average depth x 2 ft/sec flow x 60 seconds x 7.48 gallons/ft^3 + 600 gallon pump volume = 2.07 ppm formalin in river water (plug flow).

The concentration of the formalin "plug" would cause exposure of non-target organisms to 2.07 ppm formalin for 12.5 min before the plug would pass and dilution would occur. This concentration is above the 24-h LC_{50} for Ostracods. Dilution of the discharge concentration in the mixing zone 10-fold in a stream would not be considered as an unreasonable diminution of concentration. The longer the flow down the stream, the greater the dilution.

Case Situation 2

Because of the desire to maintain the treatment time as close to 1 h as possible and not extend the exposure time of the fish to formalin, albeit decreasing levels, by pumping the treatment tank/raceway at a slower rate directly into the stream, it is possible to pump the contents of the treatment tank into a holding tank or holding pond of suitable volume and pumping directly into the stream. Assume the treatment volume of the treatment tank/raceway is pumped into a holding tank/pond and an additional equal volume from a second flush of the treatment tank/raceway was added to the holding tank/pond. The total volume would be 2000 ft^3 or 14,960 gallon. The concentration of formalin in the holding tank/pond would change from 250 to 125 ppm formalin. By pumping into the same stream at 600 gallons/min, the concentration of formalin in the flow "plug" would be 1.035 ppm, very close to the idealized discharge concentration goal of 1.0 ppm. Considering the high probability of further dilution in the stream, this level should not impact adversely upon aquatic species.

Case Situation 3

This situation closely parallels case situation 1. The treatment tank/raceway contents are pumped into a holding tank/pond of suitable volume. The pumping rate was 600 gallons/min and the treatment tank/raceway is emptied by 12.46 min. The pumping rate into the hypothetical stream would be 300 gallons/min, which would yield the target discharge concentration in the stream of 1 ppm formalin. This model approach offers the operator the ability to vary the discharge rate as a function of the stream flow, and meet the proposed 1.0 ppm mixing zone concentration.

Stability of Formalin in Water

The calculated half-life of formalin in water is estimated at 36 hr. At that rate of hydrolysis and oxidation, the 1.0 ppm concentration of formalin would drop, in a static situation, to 0.06 ppm within 144 h or 6 days. Considering the further dilution of the discharge in the stream by factors of at least 10, the 1.0 ppm concentration in the mixing zone discharge should be decreased in the stream to very low levels and dissipated well before 7 days.

Environmental Effects of Formalin in the Environment

Toxicity to Non-Target Species

The following table summarizes the toxicity of formalin to other aquatic species, the non-target species that could be encountered in the aquatic environment.

Toxicity of Formalin to Aquatic Species uL/L or PPM formalin

Species	LC_{50}	Safe Conc.	Hours	$T^{o}C$
Striped Bass	15-35	---	72	21
Rainbow Trout	125-300	44.5	72	12
Lake Trout	141	---	--	12
Atlantic Salmon	389			
Chinook Salmon	---	---	--	--
Golden Shiner	62	45	72	21
Tilapia	100	100	72	21
Leopard frog Tadpole	21	---	72	21
Bullfrog Tadpole	47	---	--	21
Toad tadpole	45	---	--	21
Daphnia magna	54	13.5	--	--
Ostracods	1.15	---	--	16
Freshwater clam Corbicula sp.	800	---	--	16
Freshwater prawn Paleomonetes kadiakinesis	1105	---	--	16
Backswimmer Notonecta	4500	---	--	16
Spirogyra	---	---	--	--
Sirogonium	---	---	--	--
Stigeoclonium	---	---	--	--
Rhizoclonium	---	>100	168	--
Oscillatoria	---	>100	168	--
Ankistrodesmusfalcatus	--	~ 2.7	46 days	--

From the above data, it can be seen that there is little permanent or even transitory effect that can be expected from the use of formalin in the treatment of fish. Only if and when the dilutions in the mixing zone of the stream exceed the recommended 1.0 ppm could there be an effect upon the non-target species, such as the formaldehyde-sensitive ostracods. The combination of dilution and the rather rapid degradation of formaldehyde in the aquatic environment should provide a substantial safety factor to all species.

There is little likelihood that the biological oxidation of the formaldehyde in stream water will result in the depletion of oxygen. Since the dilutions of the treatment waters containing formaldehyde are so great, the overall concentration of formaldehyde in the stream low and the organic load provided by the formaldehyde so minimal, there should be no diminution in the dissolved oxygen of the stream, even if the temperature of the stream is warmer than the classical 21°C of many of the toxicological studies.

General Overview

The conditions required for the economic production of fish is such that it would be expected that rearing/growing facilities would be located where sufficient flowing water of reasonably high quality is available for husbandry. Usually, such aquatic systems are ecologically productive and have a large diversity of aquatic life.

There should be little or no effects upon the aquatic environment as the result of the proposed use of formalin in the control of external parasites on stripped bass. The inherent dilutions of the treatment water containing formaldehyde coupled with the relatively rapid degradation of formaldehyde in water preclude any minimal or significant effects on the environment.

Examination of case situation 3 infers that this is the best system to ensure that damage to a receiving stream will not occur. Regardless of the calculations developed, the case situation 3 model allows the greatest versatility. It allows for a storage tank/pond that permits discharge flows to be varied in respect to the flows of the receiving stream. This will allow the facility operators the flexibility to meet the idealized standard of discharge, the 1.0 ppm formalin level. As long as this target level is adhered to, there should be no damage to the non-target organisms in the receiving aquatic biosphere.

Preparation of the Environmental Assessment

This environmental assessment was prepared by Dr. Stanley E. Katz, Professor of Microbiology, Department of Biochemistry and Microbiology, Cook College/NJAES, Rutgers University, New Brunswick, NJ 08903-0231.

References

Kitchens, J.F., R.E. Casner, W.E. Harwood III, B.J. Macri and G.S. Edwards. Investigations of selected potential environmental contaminants: formaldehyde. OTS-USEPA Washington, D.C. 204 pp.

Matheson, J.C. 1981. FONSI and environmental assessment of Formalin-F as a parasiticide and fungicide in fish culture. (NADA 137-687 and MF 3543).

AMENDMENT TO ENVIRONMENTAL ASSESSMENT TITLED "ENVIRONMENTAL IMPACT ASSESSMENT FOR THE USE OF FORMALIN IN THE CONTROL OF EXTERNAL PARASITES ON FISH" (DATED JANUARY 1995)

September 6, 1995

The information provided in this amendment provides supplementary information to that provided in the EA and some clarification of information in the EA.

I. CLARIFICATIONS AND ADDITIONS TO SPECIFIC PARTS OF THE EA:

Proposed Use of Formalin

Add the following:

The proposed extension of the claim for formalin includes not only the control and prevention of external protozoan parasites on all fish, as stated in the EA, but also the use as fungicide on eggs of all fish. The proposed concentrations for treatment would be 1000 to 2000 uL/L (ppm) formalin. This concentration would be added to egg treatment containers for 15 minutes and may be repeated.

Chemical and Physical Properties of Formalin

Explanation of abbreviations (from The Merck Index, 11th Edition):

a) $d_{25/25}$ specific gravity at 25°C referred to water at 25°C

b) n^{20} index of refraction for 20°C and sodium light. The abbreviation should be n_D^{20}.

Introduction into the Environment

Add the following:

Formalin will also be used as a fungicide on eggs of all fish, at concentrations of 1000 to 2000 uL/L.

Methods of Application

Add the following:

a) Eggs are usually kept in jars or trays in relatively small volumes of water. Formalin is added to the constant flow water supply in these containers for approximately 15 minutes. The water is then flushed from the containers. The treatment may be repeated as often as five times a week (personal communication, FWS personnel, 1995).

b) The decline in concentration of formalin probably varies, depending upon conditions in the treatment facility and receiving water bodies (Helms, 1967; Kitchens, et al., 1976; Mopper and Stahovec, 1986; Hazardous Substances Data Bank, 1995).

Assessment of Impact of Formalin in the Environment

Clarification:

The assumption of a half-life of formalin as 36 hours is approximate and may apply only under certain conditions, such as the parasiticide use in fish ponds and at concentrations in the range of 20-35 uL/L of formalin (see Appendix 1 and Helms, 1967). It is reasonable to assume, however, that formalin degrades within a few days.

Additional information:

See also EA in Appendix I, under the heading, "Introduction into the Environment," for a calculation of concentrations resulting from tank treatments of 250 ppm.

Stability of Formalin in Water

Additional information:

The rate of degradation of formalin in water varies, depending upon factors such as temperature, oxygen levels, and presence of degrading microbes. For example,

a) In nutrient-enriched seawater, a lag period of approximately 40 hours precedes measurable loss of formaldehyde (Mopper and Stahovec, 1986).

b) When known quantities of formaldehyde were added to samples of water from a stagnant lake in Japan, the formaldehyde decomposed in approximately 30 hours at 20°C under aerobic conditions and under anaerobic conditions, in approximately 48 hours (Kitchens, et al., 1976). In the same study, formaldehyde added to sterilized lake water did not decompose.

c) Anecdotal evidence from FWS (see EA in Appendix I) and indirect evidence (Helms, 1967) indicates that at 20 ppm concentrations in ponds, formalin concentrations begin to decline within 30-36 hours (see EA in Appendix I).

It is reasonable to conclude that formalin biodegrades within a few days in most natural aquatic environments.

Environmental Effects of Formalin in the Environment

The following explanations concern the table titled "Toxicity of Formalin to Aquatic Species uL/L or PPM Formalin":

a) For more detailed information concerning toxicity data, including citations, and for additional toxicity data, see "Table 1. Summary of acute toxicity data for formalin in aquatic organisms" in the EA dated July 29, 1981, found in Appendix I.

b) The column labeled "Safe Conc." provides <u>maximum</u> safe concentrations, as determined by studies in which limited or no effects occurred to the organisms at the concentrations and for the time periods listed.

General Overview

Add the following information:

a) There should be no significant impacts from the proposed use of formalin in the control of external parasites on any finfish or from the proposed use of formalin as a fungicide in fish eggs.

b) See also discussion under heading, "Effects of Formalin in the Environment," in EA in Appendix I.

References

The complete citation for the Kitchens paper is provided below under the heading "Literature Cited."

II. ADDITIONAL HEADING:

MITIGATION:

See EA in Appendix I, under the heading, "Mitigation of Possible Adverse Effects." The label will require 100X dilution for contents of egg treatment tanks, rather than 75X dilution.

LITERATURE CITED

Hazardous Substances Data Bank. 1995. In Micromedex Tomes Plus, Vol. 26. Databank #164.

Helms, D.R. 1967. Use of formalin for selective control of tadpoles in the presence of fishes. Prog. Fish. Cult. 29(1): 43-47.

Kitchens, J.F., R. E. Casner, W.E. Harwood, III, B.J. Macri, and G.S. Edwards. 1976. Investigation of selected potential environmental contaminants: formaldehyde, USEPA 560/2-76-009.

Mopper K. And Stahovec, W.L. 1986. Marine Chemistry 19: 305-21.

Environmental Assessment

Use of Formalin in Fish Culture
as a Parasiticide and Fungicide

The information submitted to Master File 3543 by the Fish and Wildlife Service, Department of Interior has been evaluated. Based on the analysis of that data, we have determined that the use of formalin in accordance with the proposed action will not have any significant effects on the environment and, therefore, will not require the preparation of an environmental impact statement. Information on the environmental impacts of the manufacture of formalin must be submitted by petitioners using this Master File to support a New Animal Drug Application(s) and will be evaluated for potential significant environmental impacts at that time.

7/29/81
Date

John C. Matheson, III
Preparer and Chief
Environmental Impact Staff (HFV-310)
Bureau of Veterinary Medicine

Environmental Assessment for the Use of Formalin in Fish Culture as a Parasiticide and Fungicide

The U.S. Department of Interior, Fish and Wildlife Service, is preparing supporting information to be used by industry petitioners in a new animal drug application (NADA) which permits the use of formalin (aqueous solution of 37% formaldehyde) in food and non-food fish and fish eggs while in culture in hatcheries and ponds. Representatives of the Fish and Wildlife Service (FWS) have presented information addressing the potential for environmental impacts due to the use of formalin according to the proposed claims to be approved by FDA. The impacts due to the manufacture of formalin must be covered by those petitioners who wish to use the FWS data and this environmental assessment to support an NADA for treatment of fish. The approval of NADA's for this use is not excluded from environmental consideration under 21 CFR 25.1. The generic information supplied by FWS and FDA's environmental assessment of the use of this product reduces the information to be submitted by petitioners, as they may reference these documents in the environmental assessments which accompany their NADA's.

Description of the Proposed Action

The claims which are requested for the use of formalin in fish involve the treatment of fish eggs for fungal growth and the treatment of fish of many species in all life stages for various external parasites. The chemical would be sold over-the-counter to anyone involved in raising these fish, primarily Federal and State hatcheries and private hatcheries and fish farms. Treatment of fish would occur either in baths at high levels (up to 250 ppm formalin = 92.5 ppm formaldehyde) for short periods of time or in ponds at low levels (about 20 ppm formalin = 7.4 ppm formaldehyde) for longer periods. Egg treatments would be small volume, continuous flow treatments at 1000-2000 ppm formalin for 15 minutes. Approval of these claims would standardize and legitimize the long-standing practice of using varying concentrations of formalin in fish culture.

Introduction into the Environment

This assessment addresses only the impacts due to environmental introductions resulting from the use of formalin according to the proposed claims. Environmental releases of formalin due to manufacture must be addressed by petitioners seeking to utilize the supplemental information in preparing an NADA.

Formalin entering the environment as a result of pond treatments: Since ponds receiving formalin treatment are managed animal-raising facilities, similar to cattle feedlots, the impact of formalin treatments on the fish being raised in those ponds is the subject of the FDA's efficacy evaluation of the FWS's submission. While other organisms present in these ponds may be of concern from an environmental standpoint (e.g. populations of amphibians), they are also subject to other management strategies aimed at controlling or reducing their numbers (Helms, 1967). Therefore, the primary area of the environment where impacts of formalin releases are of concern is at the site of discharge of treated ponds. These receiving waters contain amphibians, phytoplankton, zooplankton, aquatic plants, crustaceans, and native fish populations which all constitute important parts of the natural aquatic food web.

What concentrations of formalin enter these receiving waters from treated ponds? Under normal conditions, formalin is added to ponds in a static treatment at an initial 20 ppm concentration. This concentration is not maintained and, therefore, begins to decline within 30-36 hours (Environmental Effects of Formalin Use in Fish Culture, Fred P. Meyer, hereinafter referred to as the "FWS report.") Since the fish manager would normally wish to slow this decline in treatment concentration in order to obtain maximum benefits from the money he spent on formalin, flow of water through treatment ponds would be minimized. Normally, minimal water would flow through the pond until the formalin was dissipated. Development of a low dissolved oxygen situation, either from the biodegradation of the formalin, decay of plankton killed by formalin, weather conditions, or from confining too many fish in too small a volume of water would necessitate flushing untreated water into the treatment pond and might result in formalin discharge of less than 20 ppm concentration into receiving streams. This low dissolved oxygen situation would be particularly likely to happen when the water temperature is high, since oxygen solubility in water is lowest at that time. The pond owner would seek to avoid this situation due to the unnecessary stress it would place on the fish. The techniques of (1) lowering the pond level before treatment and adding water to dilute the formalin as the oxygen demand is exerted, (2) the addition of potassium permanganate to chemically degrade the formalin after the desired treatment period, and (3) cessation of use in hot weather, are used to maintain acceptable dissolved oxygen levels and result in no discharges from the treatment area. Therefore, any discharges would be much less than the 20 ppm initial formalin concentration and of small volume from pond treatments under normal conditions (FWS report). The concentrations of formalin used are safe for the fish being treated for long periods (Burress, 1978).

Formalin entering the environment as a result of tank and egg treatments: It will be assumed that fish treatment represents a worse case than the low volume, short duration egg treatments. Therefore, estimated concentrations in the environment will be developed for fish tank treatment only.

The FWS report describes the conditions of a typical tank treatment for fish where 424.5 milliliters of formalin is added to a 450 gallon tank to result in a 250 ppm formalin concentration. The report states that most fish farms and hatcheries of economically viable size will have at least a 600 gallon per minute continuous discharge. If the tank contents were dumped within the space of 1 minute, then effluent concentration of formalin in the 1050 gallons discharged would be

$$\frac{450}{450 + 600} \times 250 \text{ ppm} = 108 \text{ ppm formalin in discharge.}$$

If the stream receiving effluent from the hatchery was small enough that it received a significant portion of its flow from the hatchery, what formalin concentrations would result? Assume that the stream averages 4 feet in width and 2 feet in depth and receives half its flow from the hatchery, 600 gallons per minute. Then:

$4 \times 2 = 8 \text{ ft}^2$ cross-sectional area of stream at the point of the discharge

$$\begin{array}{rl} 600 \text{ gallons per minute} & \text{stream flow above discharge point} \\ \underline{+1050 \text{ gallons per minute}} & \text{hatchery discharge for 1st minute} \\ 1650 \text{ gpm flow} & \end{array}$$

$$\frac{\dfrac{1650 \text{ gallons}}{1 \text{ minute}} \times \dfrac{1 \text{ ft}^3}{7.48 \text{ gallons}}}{8 \text{ ft}^2 \text{ x-sectional area}} = \frac{221}{8} = \frac{28 \text{ ft}}{\text{minute}}$$ stream velocity for 1st minute after formalin release

$$\frac{\dfrac{1200 \text{ gallons}}{1 \text{ minute}} \quad \dfrac{1 \text{ ft}^3}{7.48 \text{ gallons}}}{8 \text{ ft}^2 \text{ x-sectional area}} = 20 \text{ ft/minute}$$ stream velocity for following minutes

$$108 \text{ ppm formalin in discharge} \times \frac{1050}{1650} = 69 \text{ ppm in receiving water.}$$

Assuming "plug flow," e.g. no mixing or further dilution in the stream, no additional volume inputs (e.g. from tributaries), and no degradation or adsorption of formalin, a plug of formalin-treated water 69 ppm in concentration and 28 feet in length would move downstream. Benthic organisms, attached to rocks or in sediments, would be exposed to this concentration for 1.4 minutes. One could not expect these plug flow conditions to be maintained for more than a few minutes. Notice also that the assumption of 8 ft^2 cross-sectional area for the stream only affects the length of the "plug" of treated water in the stream: the greater the length of stream containing treated water, the longer period of time the plug flow assumption will be met. Plug flow becomes less likely to occur as the stream cross-sectional area increases because there is much greater opportunity for mixing with adjacent untreated water. Smaller treatment tank volume such as is the case for egg treatments; longer release times from the treatment tank; greater hatchery discharge volume; and greater stream flow; would all decrease the initial concentration of formalin occurring at the discharge point into the receiving stream.

<u>Fate of Formalin in the Environment</u>

Formalin combines with oxygen to yield formic acid which, in turn, combines with oxygen to yield carbon dioxide and water (FWS report).

$$\underset{\text{formaldehyde}}{H_2C{=}O} + \underset{\text{water}}{H_2O} \longleftrightarrow \underset{\text{formaldehyde hydrate (formalin)}}{H_2C\begin{smallmatrix}OH\\OH\end{smallmatrix}}$$

$$\underset{\text{formaldehyde}}{2H_2C{=}O} + \underset{\text{oxygen}}{O_2} \longrightarrow \underset{\text{formic acid}}{2\ HC\begin{smallmatrix}OH\\OH\end{smallmatrix}}$$

$$\underset{\text{formic acid}}{HC\begin{smallmatrix}{=}O\\OH\end{smallmatrix}} + \underset{\text{oxygen}}{O_2} \longrightarrow \underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O}$$

(An excellent discussion of the chemical properties, industrial uses and production of formalin is contained in Kitchens, *et al*. (1976).)

This degradation process is mediated by bacterial metabolism (Gellman, 1952). Sills and Allen (manuscript in press, attached) showed that formalin applications of 35 ppm (13 mg/l formaldehyde) to a plastic pool containing water, mud, algae, channel catfish and largemouth bass decreased to 24 ppm formalin (8.9 mg/l formaldehyde) 24 hours after treatment and that no formalin was detectable 72 hours after treatment. The investigators found no free formaldehyde retained in the tissues of the exposed fish.

Formalin oxidation may result in the depression of dissolved oxygen concentrations when the oxygen used by bacteria in the formalin oxidation process is used at a faster rate than the water is reaerated. This condition is most likely in still or slow-moving water at high temperatures because (1) bacterial metabolic activity increases with water temperature and (2) dissolved oxygen saturation level (oxygen storage capacity) and oxygen reaeration rates decrease with increased water temperature. Helms (1967) discusses this oxygen depression effect using data from aquaria (figures 1 and 2). From the figures it can be seen that the oxygen demand from formalin begins to be exerted about 24 hours after formalin application and that anaerobic conditions are more likely to occur in warmer water.

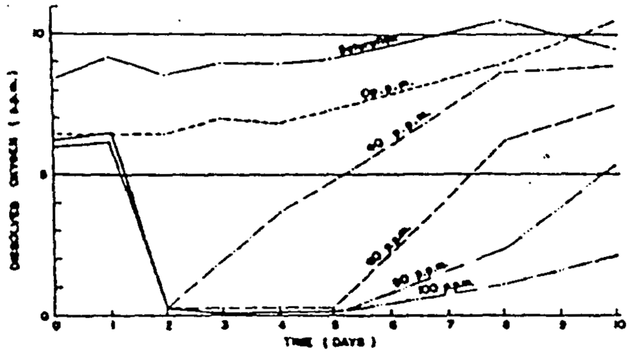

FIGURE 1.--Effect of concentration of formalin on dissolved oxygen in aquaria with water temperature of 70°F.

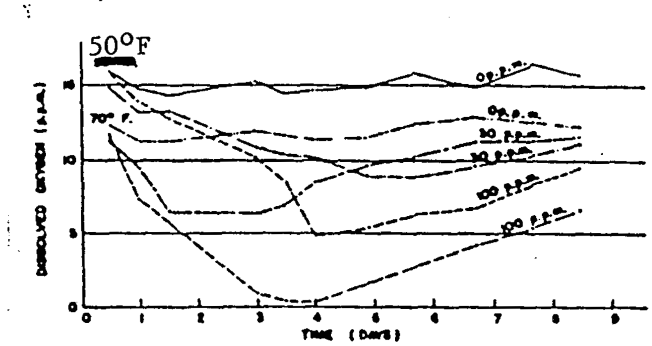

FIGURE 2.--Effect of temperature on reduction of dissolved oxygen by two concentrations of formalin.

Greater than 30-40 ppm concentrations of formalin in a 70°F body of water for about two days will result in low dissolved oxygen concentrations sufficient to kill fish and other aquatic life. Based on the expected concentrations of formalin in receiving waters at the point of discharge that would result from pond and tank treatments and the 1-2 day period for dilution to occur, it is doubtful that these formalin discharges would result in low dissolved oxygen conditions by themselves or significantly exacerbate existing decreased dissolved oxygen situations.

Effects of Formalin in the Environment

Given the expected concentrations of formalin that would result in receiving waters from the discharge of water from formalin tank and pond treatment and the expected rapid bacterial degradation of these formalin residues, acute toxicity to aquatic life would appear to be the most probable environmental effect to be observed.

The potential for acute toxicity effects to occur may be estimated by comparing laboratory data with expected environmental concentrations. Table 1 shows some of the acute toxicity data available from the literature. The limited shorter term toxicity tests available are for fish and indicate that for most fish, except striped bass, formalin concentrations of greater than 400-500 ppm are necessary to cause 50% mortality in 1 hour (Schnick, 1973). Of course, it would be expected that toxic formalin levels would be above the levels used therapeutically in fish.

Table 1. Summary of acute toxicity data for formalin in aquatic organisms.

Species	conc. of 37% formalin (μℓ/ℓ = ppm) causing 50% mortality			maximum "safe" 37% formalin concentration (μℓ/ℓ = ppm)		conc. of 37% formalin (μℓ/ℓ = ppm) causing 100% mortality		Temperature		Reference
	24 hr.	48 hr.	72 hr.	conc.	time	conc.	time	°C	°F	
Fish										
Black Bullhead catfish	70+	49	45	35	3 days	--	--	21	70	Helms, 1967
	173	--	--	--	--	--	--	12	54	Bills, Marking and Chandler, 1977
Channel catfish	86.5	67.6	67.6	48.6	1-3 days	--	--	--	--	McKee and Wolf, 1963
	87	69	69	50	1-4 days	126	1 day	25	77	Clemens and Sneed, 1958
	122	--	--	--	--	--	--	12	54	Bills, Marking and Chandler, 1977
Bluegill	--	100+	80	45	3 days	--	--	21	70	Helms, 1967
	211	--	--	--	--	--	--	12	54	Bills, Marking and Chandler, 1977
Green sunfish	323	--	--	--	--	--	--	12	54	" "
	--	--	90+	70	3 days	--	--	21	70	Helms, 1967
Largemouth bass	--	--	100+	75	3 days	--	--	21	70	" "
	283	--	--	--	--	--	--	12	54	Bills, Marking and Chandler, 1977
Smallmouth bass	222	--	--	--	--	--	--	12	54	" "

Table 1 continued.

Species	conc. of 37% formalin (µℓ/ℓ = ppm) causing 50% mortality			maximum "safe" 37% formalin concentration (µℓ/ℓ = ppm)		conc. of 37% formalin (µℓ/ℓ = ppm) causing 100% mortality		Temperature		Reference
	24 hr.	48 hr.	72 hr.	conc.	time	conc.	time	°C	°F	
Striped bass	15-35	15	15	--	--	35-40	1 day	21	70	Schnick, 1973
	--	--	--	--	--	25-30	2-4 days	--	--	--
Rainbow trout	--	≤125	--	44.5	3 days	141	<3 days	--	--	Holland *et al.*, 1960
	300	--	--	--	--	--	--	12	54	Bills, Marking and Chandler, 1977
Lake trout	141	--	--	--	--	--	--	12	54	" "
Atlantic salmon	389	--	--	--	--	--	--	12	54	" "
Chinook salmon	--	--	--	--	--	125	<3 days	--	--	Holland *et al.*, 1960
Golden shiner	87	67	62	45	3 days	--	--	21	70	Helms, 1967
Carp	--	--	70+	70	3 days	--	--	21	70	" "
Tilapia	--	--	100+	100	3 days	--	--	21	70	" "
Amphibians										
Leopard frog tadpole	22	21	21	--	--	30	--	21	70	" "
Toad tadpole	--	--	45	--	--	50	--	21	70	" "
Bullfrog tadpole	53	47	47	--	--	80	--	21	70	" "

Table 1 continued.

Species	conc. of 37% formalin (μℓ/ℓ = ppm) causing 50% mortality			maximum "safe" 37% formalin concentration (μℓ/ℓ = ppm)		conc. of 37% formalin (μℓ/ℓ = ppm) causing 100% mortality		Temperature		Reference
	24 hr.	48 hr.	72 hr.	conc.	time	conc.	time	°C	°F	
Invertebrates *Daphnia magna*	54	--	--	< 13.5	23 days	54 135	3 days 19 hours	--	--	Nazarenko, 1960
ostracods	1.15	--	--	--	--	--	--	16	61	Bells, Marking and Chandler, 1977
freshwater clam *Corbicula sp.*	800	--	--	--	--	--	--	16	61	" "
Snail *Helisoma sp.*	710	--	--	--	--	--	--	16	61	" "
Freshwater prawn *Paleomonetes kadiakinensis*	1105	--	--	--	--	--	--	16	61	" "
backswimmer *Notonecta*	4500	--	--	--	--	--	--	16	61	" "
Algae and Aquatic Plants *Spyrogyra*	--	--	--	--	--	20	7 days	--	--	Helms, 1964
Sirogonium	--	--	--	--	--	20	7 days	--	--	" "
Scenedesmus	--	--	--	--	--	25	7 days	--	--	" "
Stigeoclonium	--	--	--	--	--	40	7 days	--	--	" "
Rhizoclonium	--	--	--	>100	7 days	--	--	--	--	" "

Table 1 continued.

Species	conc. of 37% formalin ($\mu\ell/\ell$ - ppm) causing 50% mortality			maximum "safe" 37% formalin concentration ($\mu\ell/\ell$ = ppm)		conc. of 37% formalin ($\mu\ell/\ell$ = ppm causing 100% mortality		Temperature		Reference
	24 hr.	48 hr.	72 hr.	conc.	time	conc.	time	^oC	^oF	
<u>Oscillatoria</u>	--	--	--	>100	7 days	--	--	--	--	Helms, 1964
<u>Aphanothece</u>	--	--	--	>100	7 days					" "
<u>Ankistrodesmus falcatus</u>	--	--	--	~2.7	46 days	~54	46 days	--	--	" "
<u>Ceratophyllum demersum</u> (hornwort)				<2.7	25 days	--	--	--	--	Nazarenko, 1960

The most sensitive fish appear to be striped bass and channel catfish. Some organisms which serve as natural food for fish appear to be sensitive to formalin; daphnia (water fleas) and ostracods (seed shrimp) were comparable to or more sensitive than striped bass. Other aquatic invertebrates were less sensitive than fish, for example snails, clams, and backswimmers. Hornwort, a floating aquatic plant, was affected by long-term, low-level exposure to formalin, as were some but not all algae. Based on the variable sensitivity of the test species, it can be concluded that partial kills of phytoplankton and zooplankton are probable when formalin concentrations of about 10-20 ppm are maintained for greater than 24 hours. Ostracods could be expected to be killed when formalin concentrations around one part per million were maintained for 24 hours or more.

Given the proposed conditions of use, the periodic nature of the use, the rapid degradation of formalin in aquatic environments at the levels discharged, and the limited time needed for dilution of formalin to very low levels in receiving waters, it is safe to conclude that the use of formalin according to the proposed claims in the treatment of fish and fish eggs will not create significant adverse environmental effects. However, in rare circumstances, such as when effluent from fish treatment tanks or egg treatments are released into small, slow flowing or stagnant water bodies, these releases would temporarily inhibit or kill phytoplankton and zooplankton populations and, as a consequence of their decay, result in lowered dissolved oxygen concentrations. Any inhibition or damage to phytoplankton or zooplankton populations would be short-term and followed by rapid recovery.

Adherence to the cautionary instructions included on the product label (see below, Mitigating Measures) should reduce any adverse environmental impacts that might result from lack of knowledge of potential adverse effects of effluents containing formalin.

Utilization of Natural Resources and Energy

The formalin which would be used as a result of the proposed actions represents a small percentage of the total U.S. formalin use. Formalin is one of the most widely used industrial compounds, with over 50% of the annual production used to manufacture resins, which are in turn used to manufacture plastics, adhesives, compounds used in laminating, etc. (Kitchens, *et al.*, 1976). Furthermore, the proposed actions do not significantly change, only legitimize, the present use of formalin as a fish chemotherapeutant, since the use of this chemical in fish culture was not recognized until recently as requiring FDA approval.

Mitigation of Possible Adverse Effects

The following cautions are placed on the formalin label:

1. Do not use formalin which has been subjected to temperatures below 40°F or allowed to freeze. Cold or freezing causes the formation of paraformaldehyde, a substance which is toxic to fish.

2. Tolerances to formalin may vary with strains and species of fish. While the indicated concentrations are considered safe for most fishes, a small number of each lot to be treated should be used to check for any unusual sensitivity to formalin before proceeding. Striped bass (Morone saxatilis) are known to be highly sensitive to formalin so pond treatments are not appropriate for this species.

3. Under some conditions, fish may be stressed by normal treatment concentrations. Heavily parasitized or diseased fish often have a greatly reduced tolerance to formalin. Such fish do not tolerate the normal tank treatment regimen the first time they are treated, and the time or dosage may need to be reduced. If the fish show evidence of distress (by piping at the surface) the solution should be removed and replaced with fresh, well-aerated water. Careful observations should always be made throughout the treatment period whenever tank or raceway treatments are made. Treatments in tanks should never exceed 1 hour even if the fish show no sign of stress.

4. Do not apply formalin to ponds with water warmer than 27°C (80°F) when a heavy bloom of phytoplankton is present or when the concentration of dissolved oxygen is less than 5 mg/l (5 ppm). Formalin may kill phytoplankton and can cause depletion of dissolved oxygen. If an oxygen depletion occurs, add fresh, well-aerated water to dilute the solution and to provide oxygen.

5. Do not discharge the contents of fish or egg treatment tanks into natural streams or ponds without thorough dilution (greater than or equal to 10x for fish treatment, 75x for egg treatment). This will avoid damage to formalin-sensitive phytoplankton, zooplankton, and fish populations and avoid depletion of dissolved oxygen.

The last two conditions, 4 and 5, serve to prevent environmental damage by helping assure that formalin will not be used in ponds under conditions that might require a rapid release of formalin-treated water into receiving streams and providing instructions for diluting effluent from formalin tank treatments with hatchery effluent before discharge to receiving waters.

Alternatives to the Proposed Action

With the mitigating measure above, there should be no potential adverse environmental effects resulting from the use of formalin as proposed. Therefore no alternative actions will be considered. While there are no readily available substitute materials for the proposed formalin uses, it would be difficult to obtain a broad spectrum therapeutic agent with more desirable environmental fate properties: (1) simple molecule that degrades rapidly to water and carbon dioxide, (2) little bioaccumulation potential probably due to high water solubility, (3) periodic rather than continuous treatment pattern, and (4) use at facilities that would usually discharge large quantities of formalin-free effluent simultaneously with much lower quantities of the formalin-treated water.

List of Preparers

Author:

John C. Matheson, III, has served as an environmental scientist for over four years with the FDA. He received a Master of Science in Public Health in the area of Environmental Sciences and Engineering (1975) and a Bachelor of Science in Biology (1973) from the University of North Carolina, Chapel Hill, N.C. His areas of special expertise include aquatic ecology, microcosms and environmental testing standards.

Contributor:

Fred P. Meyer, Ph.D., Director, National Fishery Research Laboratory, LaCrosse, Wisconsin is the author of many articles on the use of chemotherapeutants in fish culture. He assembled the attached collection of references on the environmental impact of formalin and prepared the report "Environmental effects of formalin use in fish culture" which together served as the basis for this environmental assessment.

References

1. Burress, R. M. 1978. Effects of parasiticidal applications of formalin on nontarget organisms in ponds. U.S. Fish and Wildlife Service, Southeastern Fish Control Laboratory, Warm Springs, Georgia, Special Report. 18 pp.

2. Clemens, H. P., and K. E. Sneed. 1958. The chemical control of some diseases and parasites of channel catfish. The Progressive Fish-Culturist 20:8-15.

3. Gellman, I. 1952. Studies on biochemical oxidation of sewage, industrial wastes, and organic compounds. Thesis, Rutgers Univesity, 260 pp.

4. Helms, D. R. 1967. Use of formalin for the selective control of tadpoles in the presence of fishes. The Progressive Fish-Culturist 29(1):43-47.

5. Helms, D. R. 1964. The use of formalin to control tadpoles in hatchery ponds. M.S. Thesis, Southeastern Illinois University, Carbondale. 29 pp.

6. Holland, G. A., J. E. Lasater, E. D. Neumann, and W. E. Eldridge. 1960. Toxicity effects of organic and inorganic pollutants on young salmon and trout. State of Washington, Department of Fisheries Research Bulletin No. 5. 264 pp.

7. Kitchens, J. F., R. E. Casner, W. E. Harward, III, B. J. Macri, and G. S. Edwards. Investigation of selected potential environmental contaminants: formaldehyde. Office of Toxic Substances, U.S. Environmental Protection Agency, Washington, D.C. 204 pp. Available from National Technical Information Service, Springfield, Virginia.

8. Nazarenko, I. V. 1960. Effect of formaldehyde on aquatic organisms. Transactions of the All Union Hydrobiological Society (Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestrva) 10:170-174).

9. Schnick, R. A. 1973. Formalin as a therapeutant in fish culture. Fish Control Laboratory, Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service Publication. FWS-LR-74-09.

10. Sills, J. B., and J. L. Allen. 1979. Residues of formaldehyde undetected in fish exposed to formalin. The Progressive Fish-Culturist. (In press).