A GUIDE TO THE INVESTIGATION OF FISH KILLS

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Foreword

The Environment Programme of Enterprise Ireland provides industry, government and other agencies with a range of expertise for the control of noise, atmospheric and liquid waste discharges. The design and operation of manufacturing processes must take account of environmental impacts and, as part of its overall service to Irish industry, the Environment Programme has played a significant role in the development of practical and efficient technologies and procedures for pollution abatement.

However, it is recognised that damage to natural resources will occasionally occur, whether by accident or default, and that it is important to learn from these mistakes. Regrettably, fish kills are a reminder of the defects in our pollution control strategy and a concerted effort is required to reduce their incidence. As a contribution to this, the Environment Programme has prepared this guide in the hope that it will assist those responsible for fish kill investigations. Comments, criticisms and suggestions for revised issues will be gratefully received so that the guide will meet the needs of investigators around the country.

1.0 Fish Kill Investigation

When a fish kill occurs and a pollution or fisheries officer is called to investigate, it is not uncommon that there is a considerable delay between notification and arrival at the scene of the kill. This is frequently the reason why the cause remains unidentified. While distance is an uncontrollable factor, every effort must be made to reach the site as quickly as possible since the lethal condition is often transitory and the best chance of successful identification exists at the time the fish are dying.

In the past many fish kills have been inspected but not investigated. The officer estimated the numbers and species of fish involved, placed a few in plastic bags, filled a bottle with river water and discussed the carnage with other observers. In the absence of obvious pollution, visual or volatile, little was done to elucidate the cause of the kill other than to rely on the results of “expert” examinations of water and dead
fish. Worse still, no accurate records were kept and therefore no useful knowledge could be gained from the incident. Indeed, experience has shown that in many cases investigators were unprepared, unsystematic and sometimes negligent so that the causative agent of kills were undetected where a more competent officer would at least have narrowed down the range of possibilities.

The success rate for the solving of fish kills is low even where the best techniques have been employed – probably not much better than 20% - 30%. But the chances of success increase substantially by an informed approach to investigating which is the main reason for the preparation of these guidelines. Only by examining records over a period of years will it be possible to identify recurrent problems and thereby to eliminate the causes so that the concerned public will have confidence in the control authorities and co-operate with them. It is hoped therefore that this guide, apart from reducing the incidence of fish kills, may, where necessary, lead to tighter controls over waste inputs and an overall improvement in the quality of Irish waters.

2.0 The Fish Kill Investigator

Ideally, each county would have at least one officially appointed person responsible for fish kill investigations available on a 24-hour basis. This individual should have some training in aquatic biology and basic water chemistry including water analysis. He should also have powers of access to private property, including private residences, agricultural land and buildings and, of course, industrial premises in the course of his investigations. The person should be capable of giving evidence at court enquiries in a clear, concise manner and should be familiar with relevant legislation. Above all, the investigator must be properly equipped at all times and have immediate access to reliable transport and a telephone, the number of which should be distributed as widely as possible, particularly to angling clubs and other concerned bodies.

In practice, there are likely to be at least two agencies in each area of the country with responsibility for fish kill investigations: the Local Authority and the Regional Fisheries Board. These agencies would be well advised to have one or two officers trained for the purpose but it would be advantageous for all field workers in the public service to have a general knowledge of the relevant procedures.

3.0 Causes

In Ireland fish kills occur most often during the warmer summer months of June to September. Fish may die from a number of natural causes including suffocation, disease and sudden temperature changes. Hence the combination of salmonid mortalities and summer weather is not a chance association, merely a natural reaction to low water levels, increased temperatures and poor water quality.

A steady decline in water quality may parallel an enhancement of conditions ideal for the growth of plants, algae and bacteria due to an increasing supply of nutrients (eutrophication). Competition between plants, bacteria and animals particularly at night and in dull weather can lead to lack of oxygen, causing fish suffocation and subsequent mortality.
As dissolved carbon dioxide levels increase so also does the minimum amount of oxygen that a fish requires to survive. In situations of organic enrichment with intense microbiological activity taking place, the enhanced CO$_2$ production may be the true barrier rather than the low O$_2$ level itself.

Sudden water temperature changes can kill large numbers of fish. In large water bodies, notably lakes, sensitive species may die after swimming from deep, cold water into the warmer shallows but this is not a common occurrence in Irish waters.

Disease-caused fish deaths are seldom catastrophic and only a few dead specimens of one or more species will be evident at any time.

Rapid changes in water levels caused by flash-floods can leave fish stranded. Heavy turbidity rarely brings about the death of fish but may cause them to vacate an otherwise suitable habitat since many species cannot live for an extended period under such a condition. Where fine silt is disturbed from a lake bed (sand removal), photosynthesis may be inhibited and in extreme cases the invertebrate fauna may be reduced to tubificid worms and chironomid larvae only. Gravel beds used for spawning by salmonids may be rendered unsuitable. Land reclamation and drainage operations are frequently at fault in this regard.

Fish kills resulting from pollution may be caused by suffocation, toxic substances in the water, mechanical injury or a combination of these and other factors, including natural ones. When suffocation occurs, it is due to oxygen depletion caused by the decomposition of organic substances discharged in wastes. Most common among such wastes are improperly treated sewage, animal slurry, and food processing wastes.

Sometimes fish are killed by mechanical injury. In many cases the injuries are obvious, especially when the fish have passed through turbines or pumps. Underwater explosions may produce fatal internal injuries, but extensive kills occur only when fish are concentrated in the immediate area of the detonation.

The presence of materials toxic to fish is usually the cause of the most spectacular and serious kills. Certain chemicals used by industry are very toxic. Metals such as copper, zinc and chrome are lethal even at low concentrations and when they occur with cyanide from metal plating or metal finishing industries, serious fish kills can result. Many chemical processes produce wastes that are very acid or very alkaline. While these may kill fish, they may also greatly increase the toxicity of substances that would otherwise be harmless.

Normally, when waste is discharged continuously into a stream, it flows downstream with the current, becoming less concentrated as the processes of dilution and natural purification reduce its strength. When waste discharge is intermittent, a block of the polluting material may move downstream as an entity and, when strong enough, kill for a considerable distance. Occasionally liquid waste in road-transport containers may be accidentally or purposely dumped into rivers.

Aside from industrial pollution, inadvertent or thoughtless disposal of pesticides in watercourses is a potential source of fish mortality. The rinsing of agricultural spray
equipment, careless pumping of stream water into spray tanks and dumping unused portions of pesticides into a stream may have serious consequences.

Often fish will move to escape pollution, either swimming ahead of it or dodging into tributary streams where they remain until the unfavourable conditions have passed. There are, however, substances, such as phenol, which fish do not recognise as dangerous and do not avoid. Moreover, a few substances, such as chlorine, which are directly harmful, attract fish so that they swim towards an increasing concentration and their ultimate destruction.

4.0 Field Investigation

The following section give a step-by-step procedure for sampling and observing conditions at the scene of a fish kill so that the maximum amount of useful information is obtained. The sequence of sampling is important because the lethal condition will be transitory and may already have diminished. For this reason, Steps 1 to 3 should be carried out speedily. Familiarity with the procedure will ensure efficiency in the field.

Whenever possible, water and effluent samples should be taken in duplicate but this could prove impractical where access to the site is difficult. Immediate and complete labelling of samples is most important. Details should include date, time, water body and exact location in addition to any numbering system adopted.

The procedure assumes the availability of certain equipment items. A list of essential as well as useful items will be found in Appendix 1. Appendix 2 gives an example of a report sheet that should be completed as far as possible before leaving the site.

Step 1A. Take Samples of Water

- On arrival, take the water samples in the immediate area of the dead or dying fish (Station 1). Using two clean one-litre bottles, sample close to the shore but avoid stagnant water. Some surface water should be included.

  Note: Lacking an obvious source of pollution, it may be assumed that Station 1 is the most contaminated area.

Step 1B

- Quickly examine one or two fish for external abnormalities such as skin discolouration, spinal curvature, and distended, pale or darkened gills. Do not try to determine the species at this stage, or measure or collect samples.

Step 2. Measure Dissolved Oxygen and Temperature

- Perform a quick air-calibration test of the dissolved oxygen meter and electrode in accordance with the manufacturer’s instructions to confirm the accuracy of the instrument. If major re-adjustment is necessary dispense with the meter and resort to chemical oxygen measurement (Winkler Method).
• Measure and record dissolved oxygen and water temperature at Station 1 using both electrometric and Winkler methods (see Note 1).

• Proceed upstream taking sufficient dissolved oxygen readings to establish the presence or absence of abnormally low values (see Note 2).

**Note 1:** This could be important where court action is envisaged.

**Note 2:** Where extensive growth of plants or algae occurs, and dead fish are discovered in the early morning, check dissolved oxygen during the night time following.

**Step 3. Locate Discharges Upstream of Kill**
- Explore both sides of the river meticulously and sample all inputs (ditches, drains, outfall pipes and tributaries) suspected to contain polluting materials. Measure dissolved oxygen, temperature and pH at each location where a sample is taken. Remember to take a sample upstream of any possible source of pollution; this is essential in detecting changes in water quality.

**Step 4. Mapping the Kill**
- Establish the upstream and downstream limits of dead and dying fish. Record this information as accurately as possible on the largest scale map available.

- Take photographs depicting the extent and severity of the kill. If it is practicable to include landmarks, do so. Close-ups showing the range of species and sizes are desirable.

- Obtain an accurate count or, where numbers are large, a good estimate of the affected fish. Record species involved and their average length.

- Take a representative sample of the fish, wrap individually in tin foil and place in a plastic bag.

**Step 5. Check Biological Conditions**
- Examine the underneath of stones and pieces of aquatic plant for the presence of invertebrate organisms such as caddis larvae, may-fly and stone-fly nymphs, flatworms, snails and amphipods. Their total absence, or the presence of dead or dying specimens may provide an important clue to the type of pollution that has occurred. Check sediment-dwelling invertebrates only if other substrates are absent.

- Note the presence of heavy growths of aquatic plants, surface films of algae or blankets of sewage fungus.

**Step 6. Complete the Picture**
- Obtain an estimate of the river flow from average depth, width and velocity (using a meter or floating object timed over a fixed distance). This can be compared to existing records.
• Measure air temperature and ascertain weather conditions in the area over the preceding 48 hours. Try to determine the extent of cloud during this interval since exceptionally dull weather influences oxygen content of the water.

• Make preliminary contact with all persons on hand at an early stage of the kill so that, if necessary, detailed statements may be obtained later.

• Enquire into the recent use of pesticides, transport accidents or illegal dumping in the area. Try to determine the source of any suspected discharges.

• Where metal pollution is suspected, take 100-200 ml. sub-sample from the relevant bottles and acidify with about 5 drops of nitric acid. Label accordingly.

• Check the labelling of all samples. Place water samples in a suitable box and lock it. Return them to the laboratory without delay, particularly where ammonia and B.O.D. measurements are required. If storage is necessary, keep the samples cool and in a secure place. Fish should be frozen as quickly as possible.

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5.0 Evidence From Dead Fish

It is seldom that the cause of a fish kill can be precisely determined from an examination of dead specimens. Chemical analysis of water and effluent samples is in general more productive. Therefore, do not be tempted to rely on a pathologist’s report to solve the problem.

Sudden mass mortality over a period of hours cannot be due to infectious disease or parasitism. Furthermore, few toxic substances produce symptoms that are characteristic of one substance only. The following table lists some of the more readily observable symptoms and their causative agents.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Possible Causes</th>
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<tbody>
<tr>
<td>White film on gills, skin or mouth</td>
<td>Acids, heavy metals, trinitrophenol</td>
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<tr>
<td>Damaged gill epithelia</td>
<td>Copper, zinc, lead, detergents, ammonia, quinoline</td>
</tr>
<tr>
<td>Dark red gills</td>
<td>Low oxygen, phenols, p-cresol, Naphthalene</td>
</tr>
<tr>
<td>Bright red gills</td>
<td>Cyanide</td>
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<tr>
<td>Yellow gills</td>
<td>Dieldrin</td>
</tr>
<tr>
<td>Distended gill covers</td>
<td>Phenol, cresol, ammonia, cyanide</td>
</tr>
<tr>
<td>Haemorrhage from gill slits.</td>
<td>Detergents</td>
</tr>
<tr>
<td>Silt-clogged gills</td>
<td>High turbidity, ferric hydroxide</td>
</tr>
<tr>
<td>Swollen abdomens</td>
<td>Certain chlorinated hydrocarbon insecticides.</td>
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</tbody>
</table>
Analysis of tissue can be complex and expensive and it is rare for toxic substances to leave detectable residues in tissue after only a brief exposure. Therefore, when submitting fish tissues for analysis it is essential to have a good indication of the possible causative substance and to instruct the analyst accordingly. Zinc, copper, mercury, cadmium, phenolic compounds and some pesticides can be detected in fish following lethal doses but concentrations must be compared to control specimens.

6.0 Legal Action

Where an investigation leads to the conclusion that a fish kill was caused through irresponsibility, neglect or wilful intent, and was clearly in violation of the laws pertaining to fishery and water quality protection, legal action should be contemplated. Therefore, each investigation should be approached with this possibility in mind.

Remember that any facts or data presented in evidence at court proceedings must be well substantiated. The accuracy of analytical measurements, locations of samples, times, dates and other relevant information should always be well documented. The completion of a report form, such as that shown in Appendix 2, immediately after the field investigation is a pre-requisite in this regard.

There must be no possibility of water samples being mixed up by the investigator or the analyst or, indeed, by outside interference. Complete labelling of bottles, transport in a locked box and a signature from the analyst on receipt at the laboratory are wise precautions.

Field instruments for measurement of dissolved oxygen, pH and temperature must be properly calibrated and the investigator should retain records of calibration.

These measurements must be performed at the time of sampling. Samples for ammonia and B.O.D. determinations must be analysed on the day of sampling. Some other parameters require special preservation, and advice on this should be obtained from an experienced analyst.

Photographic records of the fish kill detailing the extent, location and species affected can be valuable in court action. Photographs should be clearly labelled on the reverse showing date, time, waterbody and townland.

Names and addresses of witnesses to the fish kill should be obtained, particularly those who were at the scene prior to the investigator. Where industrial concerns are implicated the names and addresses must correspond precisely to those listed by the Company Registration Office. Correct spelling of all names is essential.

Interpretation of field and laboratory results can be the most difficult aspect of preparing a case. Where a defendant is in default of a local authority discharge licence the conditions of the licence must be carefully reviewed and compared to analytical results on effluent samples collected. Quality objectives, such as those given in the
various EU Directives, can be used to show that maximum or minimum values for certain parameters were exceeded, but may not be sufficient to confirm the presence of a lethal condition. Particularly where oxygen, temperature or toxic substances are implicated, the advice of an experienced fishery biologist or toxicologist may be necessary for the proper interpretation of field and laboratory data. Where necessary, appropriate experts should be called upon to give testimony.

**APPENDIX 1**

**Essential equipment**
- Bags (large plastic)
- Bottles (at least ten 1 litre plastic or glass)
- Bottles (250 ml. glass stoppered for Winkler test)
- Box (padlocked) to hold water samples
- Camera (preferably focusing to 1.5 m or less)
- Dissolved oxygen meter
- Felt marker, note book and pencils
- Maps
- Meter stick and stop watch
- pH meter (battery operated)
- Pipettes (2 x 2 ml glass)
- Reagents for Winkler test and preservatives (see below)
- Tape measure
- Thermometer
- Tin foil
- Waders (preferably chest length)

**Useful extras**
- Flow meter
- Inflatable boat (compact 2 – 3m)
- Invertebrate sampler (Surber-type or equivalent)
- Net (long handled for fish retrieval)
- Styrofoam cooler or ice chest
- Water sampler and cable

**Reagents**
- Manganese sulphate and alkali-iodide-azide reagents (Winkler)
- Sodium hydroxide (concentrated for cyanide preservation at pH10)
- Nitric acid (concentrated for metals preservation)
APPENDIX 2

Sample record sheet

Waterbody (river, lake, etc.): _____________________________
Townland: ____________ County: ___________
Date: _______ Time Reported:____Reported by:______________
Time of investigation: _______

A. Stream Conditions
Flow rate:___m/sec.,__Mean depth:___m.,Mean width:___m.
Water level:__Normal,___high,___low.
Odour:_____Turbidity:____Colour:____Surface films:____
Weather in last 48 hours (air temp, cloud cover and rainfall):

B. Sources of Pollution.
Industries, towns or individuals discharging to sewer or ditch:

Nature of wastes : ________________
Estimate of waste flow:___________ Duration:_____________

C. Fish mortality.
Most upstream location of dead fish:* 
Distance downstream that fish were killed:* 
Approximate number of fish killed:____________________
Species affected (% of each):___________________________
Invertebrate life affected:_____________________________
*Indicate on map overleaf.

Record of samples and tests.

<table>
<thead>
<tr>
<th>Station</th>
<th>Water sample D.O. mg/l</th>
<th>Temp °C</th>
<th>pH</th>
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E. Sketch map of waterbody indicating sample stations, outfalls, landmarks and extent of kill:
Name of investigator_______________________ Position:________
### SUMMARY OF INSTRUCTIONS:


2. Get to the scene of the kill as quickly as possible after notification.


4. Do not delay in having samples analysed.

5. Complete the report form immediately after the field investigation.

6. If necessary obtain assistance with interpretation of test results.