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# Impact from a cattle waste lagoon rupture on a downstream fish farm: a case study

Ana De la Torre [1,✉], Lucas Domínguez [2], Miguel González [1], Sonia Aguayo [2], Matilde Carballo [1] & María Jesús Muñoz [1]

1. *CISA-INIA, Madrid, Spain*
2. *Department of Animal Production I, Facultad de Veterinaria, Universidad Complutense de Madrid, Spain*

**Abstract.** A retrospective diagnosis of a massive fish mortality in an aquaculture facility was performed following a cattle waste effluent spill to a river used as source for the fish farm. The level of suspended solids and non-ionised ammonia ($NH_3$) reaching the farm were estimated based on concentrations in the animal waste and the dilution factor in the river. The calculations indicate that both concentrations were higher in the fish farm after the leakage than the lethal concentrations reported in water quality criteria for freshwater fish. Therefore, these calculations tie the cattle waste leakage to the fish kills observed.

[Keywords: diagnose, rainbow trout kill, ammonia, suspended solids, non ionised ammonia, animal waste]

**Resumen. Impacto en una piscifactoría por rotura de una balsa de purines vacunos: un estudio de caso**: Se presenta un diagnóstico retrospectivo de la mortalidad masiva de truchas ocurrida en una piscifactoría tras el derrame accidental de un vertido de purines aguas arriba de dicha piscifactoría. Se calcularon las concentraciones de amoníaco no ionizado ($NH_3^+$) y de sólidos en suspensión en el agua de la piscifactoría tras el vertido, considerando su concentración en el purín y el factor de dilución del vertido. Estos cálculos indicaron que las concentraciones de sólidos en suspensión (6541.1 mg/L) y de $NH_3^+$ (1.26 mg/L) eran superiores a las concentraciones letales descriptas en los criterios de mortalidad para peces, indicando que el vertido de purines estaba implicado en la mortalidad ocurrida en la piscifactoría.

[Palabras clave: diagnóstico, mortalidad de trucha arcoiris, sólidos en suspensión, amoniaco no ionizado, residuo animal]

## Introduction

Livestock farm wastes are involved in many pollution events in surface waters. A common method of animal waste handling for industrial-style livestock production facilities is to pump it into open-air called lagoons. In North Carolina (USA), 20% of 4000 industrial-style farms violated regulations and 5% caused severe impacts on surface waters (Costelo & Gamble 1992; North Carolina Coastal Federation 1996; Burkholder et al. 1997). In other countries, such as United Kingdom or Spain, the number of these accidents has increased recently, making up 17% of recent pollution incidents (National Rivers Authorities 1990; Department for Environment, Food and Rural Affairs 2002). Surface water pollution owing to livestock wastes now ranks fourth highest in environmental legal accusations (Pérez de Gregorio et al. 2003). Many of these incidents are related to rupture seepage or overflowing of animal waste lagoons after

✉ CISA-INIA, Valdeolmos, 28130 Madrid, Spain. torre@inia.es

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precipitation events. The reported water pollution incidents involving farm organic wastes (US Environmental Protection Agency 1998; Department for Environment, Food and Rural Affairs 2003) indicate that cattle farms caused around 30% of the spills and catastrophic runoff impacts.

Available monitoring studies have demonstrated that animal waste spills cause deleterious effects on fish and wildlife resources from high biochemical oxygen demand and decreased dissolved oxygen, excessive eutrophication from addition of high nutrient concentrations such as ammonia, phosphorus, and organic carbon, and high densities of pathogenic microorganisms (US Environmental Protection Agency 1998; Mason 2002). Burkholder et al. (1997) and Mallin (2000) documented that anoxic conditions (< 1 mg DO/L), high turbidity (> 70 mg/L of suspended solids), and high ammonia (> 40 mg total $NH_4^+$/L) occurred in receiving waters after an accidental swine waste dump (> 40 x $10^6$ L), causing mass fish mortality. In the mid-long term, the nutrient load from that spill was related to noxious phytoplankton blooms including ichthyotoxic algae and to an ulcerative epizootic and fish kill. Livestock wastes (mainly hog and dairy operations) have also been associated with reduced survival and species losses of fish and aquatic invertebrate (Soto-Galera et al. 1999; Department for Environment, Food and Rural Affairs 2003).

Monitoring studies in streams receiving drainage waters from intensive dairy farming activities have shown poor biological quality associated to low dissolved oxygen levels and high concentrations of biological oxygen demand (1.8-73.5 mg BOD/L) and ammonia nitrogen (3-20 mg $NH_4^+$/L) (Department for Environment, Food and Rural Affairs 2003). Massive fish mortalities after cattle waste dump have also been described by US Environmental Protection Agency (1998) such as in Wabasha County, MN (May 1997), where a dairy manure release killed 16500 minnows and white suckers, and in Kitchen Creek, WV (August 1998), where a runoff from cattle manure pond affected 3.4 km of stream killing 13693 fishes (rock bass, minnows, suckers, mangined madtom, darters and sculpin).

Different environmental strategies have been adopted. Open-air waste pits are now regulated in North America (by federal and state agencies) and Europe (by the European Union), but violations of regulations are common and risks persist (US Environmental Protection Agency 1998). The repercussion of those incidents is also high in Mediterranean countries, where different animal production systems coexist in rural areas. Legal or economic responsibilities are frequently invoked for which technical studies are frequently required after the event to assess the extent of the pollution from animal waste seepage or spills. This paper presents a retrospective diagnosis of a massive fish mortality in a fish aquaculture facility after an accidental cattle waste discharge.

## METHODS

An accidental discharge (375000 L effluent within 4 hours) was caused by the rupture of a hatch from a cattle waste lagoon in Lugo, Galicia, Spain (Figure 1). The effluent reached a stream of the Eo River, where the receiving water point of the fish farm was situated (140 m downstream). The fish farm was specialised in rainbow trout (*Oncorhynchus mykiss* Walbaum) production. It took water directly from the stream and directed it through the installation, avoiding recirculation (Figure 1). After the incident, 480000 fry and 183500 adults were dead, and the farm lost its commercial capacity for 10 months.

A field study was performed 18 days after the incident, requested by the fish farm, to assess the impact of the cattle waste discharge on the massive fish mortality. Stream water samples were collected from four locations along a 50-m segment of the river, upstream and downstream of the cattle farm (Figure 1). The pH and dissolved oxygen were analysed in situ using an Orion SA 250 pH meter (Orion Research AG, Atlanta, Georgia, USA), and a YSI 5700 series dissolved oxygen meter (Yellow Springs Instruments, Brannum Lane, Ohio, USA). A slurry sample was collected from the cattle waste lagoon. Density (American Public Health Association, American Water Works Association & Water Pollution

Control Federation 1992), total nitrogen (Orion electrode 95-12 Research AG, Atlanta, Georgia, USA), conductivity and temperature (Orion conductivity meter Research AG, Atlanta, Georgia, USA), pH (as above), total ammonia (Orion 95-12 electrode, Orion Research, Atlanta, Georgia, USA), non-ionised ammonia ($NH_3^+$; Alabaster & Lloyd 1980), dissolved oxygen (as above), and suspended solids (American Public Health Association, American Water Works Association & Water Pollution Control Federation 1992) were analysed. The $NH_3^+$ and suspended solids concentrations in the fish farm were estimated as:

concentration in the fish farm = concentration in the slurry/dilution factor,

where the dilution factor was:

(river flow + spill flow)/spill flow (spill volume/spill duration) flow

## RESULTS

The analysed parameters (means ± SE) in the river water were 7.7 ± 1.0 mg/L for dissolved oxygen, and 6.5 ± 0.3 for pH. The analysed parameters in the cattle waste are included in Table 1.

## DISCUSSION

At 18 days after the cattle waste effluent spill when this retroactive field study was performed, pH and dissolved oxygen levels (means ± SE) in river water were similar to typical values recorded in that river (dissolved oxygen: 9.8 ± 1.3; pH: 6.7 ± 0.4; data from Ministry of Environment, Division of Water Quality Control and Treatment), and within the acceptable water quality criteria (dissolved oxygen: > 5.0; pH: 6.0-9.0; European Commission 1978; US Environmental

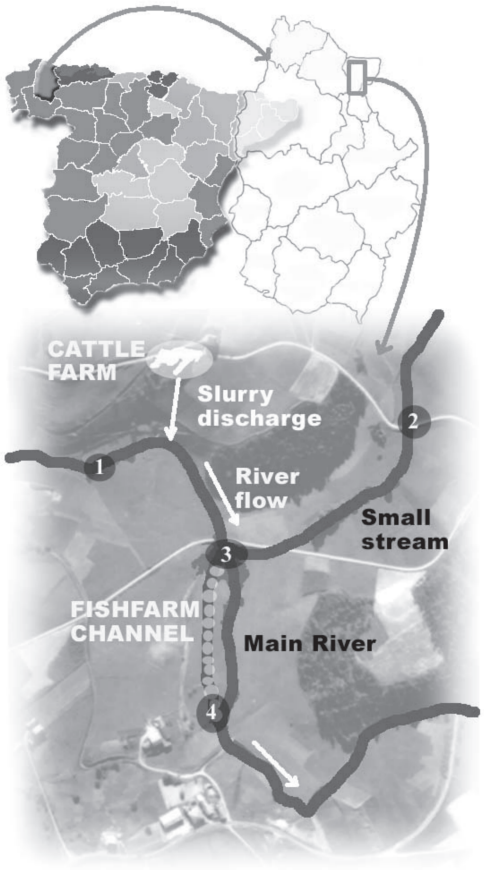


**Figure 1**. Location of the accidental discharge caused by the rupture of a hatch from a cattle waste lagoon in Lugo (Galicia, Spain).

**Figura 1**. Ubicación de la descarga accidental causada por la rotura de una balsa de purines vacunos en Lugo (Galicia, España).

**Table 1**.- Physical-chemical data from the analysis of the cattle waste samples from the accidental discharge in Lugo (Galicia, Spain).

**Tabla 1**.- Datos físico-químicos de los análisis realizados en las muestras de la descarga accidental de purín vacuno en Lugo (Galicia, España).

| Parameter | Value |
|---|---|
| Density (g/cm$^3$) | 1017 |
| Total nitrogen (kg/m$^3$) | 2.2 |
| Temperature (ºC) | 20 |
| pH | 7.5 |
| Dissolved oxygen (mg/L) | 0 |
| Conductivity (mS/m$^3$) | 7000 |
| Suspended solids (mg/L) | 61800 |
| Total ammonia (mg/L) | 44 |
| Free unionised ammonia (mg/L) | 11.9 |

Protection Agency 1986). Hypoxia/anoxia from depleted dissolved oxygen represents one of the main causes of immediate fish mortality after animal waste discharges (Burkholder et al. 1997; Mallin 2000). Although all shoreline vegetation died during this cattle waste effluent spill, suggesting anoxic conditions, its role in the event could not be assessed adequately since dissolved oxygen levels had recovered to normal 18 days after the event. As a consequence, a protocol involving estimated parameters had to be applied to establish the cause-effect relationship.

The cattle manure composition (Table 1) was similar to those described in previous studies (Monge et al. 2001; Díez et al. 2001, 2003). Based on the cattle waste slurry analytical results and the available information from official reports (river flow: 220L/s; spill: 375000 L/4 h; data from Ministry of Environment, Division of Water Quality Control and Treatment), the concentrations of suspended solids and $NH_3^+$ that entered the fish farm were estimated at 6541.1 mg/L and 1.26 mg/L, respectively.

The suspended solids concentration was much higher than the maximum level recommended to protect aquatic biota (25 mg/L), and more than 20-fold higher than levels known to be lethal to fish (Alabaster & Lloyd 1980). The free (unionised $NH_3$) concentration was also much higher than the lethal concentration reported for salmonids (0.2 mg free $NH_3$/L; Alabaster & Lloyd 1980). High quantities of suspended solids can cause fish asphyxia resulting in a direct but not immediate effect (Alabaster & Lloyd 1980), while severe acute effects from short-term exposure to excessive ammonia (< 3 h) have included gill hyperplasia, which decreases fish respiratory efficiency (Tarazona et al. 1987). Use of sewage effluents as a water source at 0.1% dilution (fish farm water 0.1-0.2 mg free $NH_3$-N/L) similarly has led to adverse effects (Costelo & Gamble 1992). As Liang & Wong (2000) have demonstrated, fish are more sensitive to total ammonia when the fish farm uses waste effluent as a water source, indicating that removal from the sewage effluent is necessary before being used for fish culture.

In conclusion, the fish mortality event observed in the fish farm after the cattle waste effluent spill was attributed to toxic unionized (free) ammonia concentrations that were estimated to have occurred during the event, together with high suspended solids levels that can promote fish suffocation, and hypoxic or anoxic conditions favoured by the organic-rich waste.

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