THE INFLUENCE OF TRANSIENT PHENOMENA ON THE 
BIODEGRADATION OF NITRILOTRIACETIC ACID IN THE 
ACTIVATED SLUDGE PROCESS I: VARIATIONS IN 
HYDRAULIC LOADING AND SEWAGE STRENGTH

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Abstract. The removal of nitrilotriacetic acid (NTA) following acclimatization in an activated sludge pilot plant has been studied during transient changes in operating conditions. These changes included increases in hydraulic loading and influent chemical oxygen demand (COD) and such phenomena in combination with transient temperature reductions. Short-term increases in hydraulic loading from 1 to 2 dry weather flow (dwf) had a very limited effect on NTA removal. Increasing the influent COD had a slight effect on NTA removal. Short term increases in hydraulic loading combined with transient reductions in temperature significantly reduced NTA removal. The effect of these combined changes on NTA removal was synergistic, rather than additive. Increases in influent COD combined with transient temperature reductions also caused a significant reduction of NTA removal. The effect of such combined changes on NTA removal was at most only additive.

1. Introduction

Phosphates from detergent builders that enter bodies of water via sewage treatment works have been blamed for eutrophication (Lee et al., 1978; Hartig and Horvath, 1982). An alternative detergent builder, NTA, is currently in widespread use in Canada and is used to a limited extent as a detergent builder in Sweden (Taylor, 1980), Switzerland (Perry, 1981) and The Netherlands (De Oude, 1982). However, the use of NTA was discontinued in the USA in 1970 as a result of concern expressed by the Surgeon General (International Joint Commission, 1978) and has subsequently been implicated in the formation of carcinogenic tumours in rats (Goyer et al., 1981).

Nitrilotriacetic acid used in detergents will reach waste water treatment plants via the sewerage system. “Reductions in NTA concentrations which occur as waste water flows through treatment plants are ordinarily assumed to be attributed to biological degradation” (International Joint Commission, 1978). Thus the removal of NTA is substantially dependent upon secondary biological treatment as only limited removal of NTA is expected during primary sedimentation (Rossin et al., 1982a). Biodegradability tests on NTA have been inconsistent (Means and Anderson, 1981) but after a period of acclimatization near complete biodegradation can be achieved under optimum conditions in the activated sludge process. (Gudernatsch, 1970; Stoveland et al., 1979a; Rossin et al., 1982b).

The period of acclimatization prior to NTA biodegradation and the subsequent efficiency of NTA removal during biological waste water treatment is affected by such
factors as treatment temperature (Eden et al., 1972; Stephenson et al., 1983a); process parameters (Obeng et al., 1981; Rossin et al., 1982b; 1983); NTA loading (Stoveland et al., 1979b; Wei et al., 1979); water hardness (Björnsl et al., 1972; Stoveland et al., 1979a) and concentration of metals (Warren, 1974; Rossin et al., 1982b, 1983).

The temperature of a sewage treatment works will alter rapidly due to extremes of weather conditions including storms and thaws (Särner and Marklund, 1982). In temperate zones such as the United Kingdom the average temperature of a typical sewage treatment works during the 4 mo of winter can be below 12 °C with a minimum of 3 °C (Obeng et al., 1982). At temperatures down to 4 °C solids and biochemical oxygen demand (BOD) removal by the activated sludge process are only slightly affected (Sayigh and Malina, 1978) but at temperatures below 15 °C nitrification can be inhibited (Randall et al., 1982). Less efficient removal of NTA during the activated sludge process at low temperatures has been demonstrated in laboratory simulations (Bouveng et al., 1968; Eden et al., 1972; Shannon et al., 1978; Obeng et al., 1982), pilot plants (Stephenson et al., 1983a; Van’t Hof et al., 1983) and full scale treatment works (Gudernatsch, 1974; Wei et al., 1979).

Less efficient removal of NTA during activated sludge treatment has been observed when the treatment temperature was maintained at less than, or equal to, 10 °C (Perry et al., 1984). Bouveng et al. (1968) reported removals of NTA in laboratory activated sludge units of 25% at 5 °C. Eden et al. (1972) achieved essentially complete biodegradation of influent NTA concentrations of 5 and 20 mg L⁻¹ at 20 °C but virtually no removal was observed at 5 °C. In laboratory scale batch activated sludge experiments biodegradation rates of complexes with several metals (Ca, Cd, Cr, Cu, Fe, Pb, Hg, and Ni) were greatly reduced at 5 °C compared to 15 °C (Shannon et al., 1978). The few experiments conducted at 10 °C indicated little difference from degradation rates at 15 °C (Shannon et al., 1978). Low temperatures also decrease the removal of NTA to a similar degree in aerated lagoons (Rudd and Hamilton, 1972; Rudd et al., 1973) and trickling filters (Bouveng et al., 1970; Cleasby et al., 1974). In experiments using laboratory scale activated sludge simulations Obeng et al. (1982) demonstrated that there was no adverse effect on NTA biodegradation when the temperature was decreased from 17.5 °C to approximately 12.5 °C over 4 hr, remaining at 12.5 °C for a further 8 hr. Two experiments with a reduction in temperature from 17.5 to 9.5 °C over 8 hr, remaining at 9.5 °C for 6 hr before returning to 17.5 °C, resulted in decreases in NTA removal from 98 to 60% and from 95 to 57%. A series of experiments using an activated sludge pilot plant treating settled sewage demonstrated that transient temperature reductions from 17.5 to 10 °C caused a slight decrease in NTA removal (Stephenson et al., 1983a). The decrease in NTA removal was more significant during temperature reductions from 17.5 to 7.5 °C and reductions from 17.5 to 6 °C resulted in a substantial decrease in NTA removal. Analysis of data for a full scale activated sludge plant revealed a significant difference in NTA removal between 15.5 and 9.4 °C and between 14.5 and 10.3 °C for influent concentrations of 2.5 mg L⁻¹ and 20 mg L⁻¹ respectively (Wei et al., 1979). Studies of other full scale treatment works have demonstrated a decrease in NTA removal in winter compared to summer (Shumate et al., 1970; Gudernatsch, 1974). The effect of temperature on NTA removal during activated sludge treatment is summarized in Table I.