The Potential for the use of Willow (*Salix* spp.) in Buffer Zones for Reducing Nitrate and Atrazine Pollution

In 1980, the EC Nitrate Directive was established following the European Community Directive on the Quality of Water Intended for Human Consumption. This environmental measure is intended to protect human health and the environment by ensuring that the levels of nitrate (NO_3^-) in surface and ground waters, do not exceed the 'Maximum Acceptable Concentration' (MAC) of 50 gm $^{-3}$.

Nitrate in many water sources currently exceeds these concentrations and the number of offending samples is increasing. In addition to interfering with the human use of water supplies, nutrient enrichment (eutropication) of surface waters is also detrimental to aquatic ecosystems, leading to algae blooms, decreased light penetration, lower dissolved oxygen and biomass production. Sources of NO_3^- pollution in surface and ground waters include the atmosphere, leaking sewers, septic tanks, air field runway de-icers, sewage sludge applications to land and urban waste treatment plants, however the main polluting source by far is agriculture.

There are various preventative policies that can be implemented for reducing NO_3^- levels such as the reduction of fertiliser inputs in agriculture and the implementation of good farming practices. Although these polices have multi-use perspectives and ensure the long term maintenance of resources, it is claimed by some these can cause agricultural activities to become restricted, reduce farm incomes and depress land values. Curative measures (e.g. water denitrification technology) have a single use perspective and perennial costs but are likely to be more expensive in the long run. It is clear that alternative, novel approaches that integrate options for both the short-term and long-term are required.

Research has shown that vegetated buffer zones planted alongside watercourses can improve the quality of runoff water with respect to certain contaminants particularly NO_3^-, phosphate and some pesticides. Based on findings, Riparian Buffer Zones (RBZs) have been identified as a Best Management Practice to reduce diffuse pollution from agriculture.

Riparian ecosystems occupy a narrow belt of land along streams and around lakes and wetlands. Because of their landscape position and their more frequent natural disturbance (e.g. flooding), riparian zones contain sharp biological and physical gradients. This results in a biological community that consists of both upland and aquatic species, together with those adapted specifically to the riparian habitat. For this reason riparian ecosystems are important for maintaining biodiversity. Additionally, they perform important functions in agricultural and grazing landscapes, such as filtering and retaining sediment, immobilising, storing and transforming chemical inputs, maintaining steambank stability, modifying aquatic ecosystems and providing water storage and recharge for subsurface acquifers.

The objective of this research thesis was to analyse the potential use of willow in buffer zones for reducing nitrate and atrazine pollution. Willow are tolerant of a wide range of climatic and edaphic factors and occur in all continents. The study examines the capacity of young willow cuttings to remove NO_3^- from nutrient solutions in controlled environment conditions. Most of the experiments described in this thesis were performed using *Salix viminalis* 'Bowles hybrid' – a very fast growing shrub species with great potential for biomass

production. For comparison *S. triandra* 'Whissender' - a robust bushy shrub or small tree was used, plus in one experiment perennial rye grass (*Lolium perenne'*) was also examined.

Two types of NO_3^- uptake are identified, the first is NO_3^- which is absorbed and reduced to amino acids (primarily in the root), which is then utilised for growth (growth NO_3^-). Additionally, NO_3^- is also absorbed in amounts that exceed short-term growth requirements (luxury NO_3^- uptakes). Nitrate reduction in the roots by the enzyme nitrate reductase is adequate for growth. Consequently, NO_3^- absorbed in luxury amounts is transferred to the leaves unchanged. Here nitrate reductase activity is stimulated presumably in response to the increased delivery of NO_3^- via the xylem, Since NO_3^- *per se* did not accumulate in foliage it is concluded that amino acids formed are incorporated into specific storage proteins in the leaves and woody tissue. There was no evidence of negative signals regulating nitrate uptake by the root to growth demand by the shoot.

Herbicide tolerance is a pre-requisite for buffer zones plants to function dependably. Willows were shown to withstand atrazine and mecoprop pollution at levels exceeding those found in field drains ($10mgm^3$). Additionally, substanital amounts of atrazine ($4.6ng\ h^{-1}\ g^{-1}$ leaf (fresh weight)) are translocated to the growing shoot and metabolised.

All the results of this study suggest that willow has a large store capacity for N as protein and can therefore absorb substantial quantities of NO_3^-. Planted in well managed buffer zones, willows have useful potential for actively hindering the passage of NO_3^- to surface waters particularly in maize and cereal cropping areas where altrazine and mecoprop are used extensively.

This R&D Technical Summary has been adapted from thesis:

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A copy of this thesis is available at the University of Bristol and in the Environment Agency Library and Information Centre at Tyneside House, Newcastle upon Tyne.