Der Tropenlandwirt, Zeitschrift für die Landwirtschaft in den Tropen und Subtropen
83. Jahrgang, Oktober 1982, S. 155 - 165

Treatment of Rural Wastewaters in Australia with Aquatic Plants: A Summary

Behandlung ländlicher Abwässer mit aquatischen Pflanzen in Australien: eine Zusammenfassung

C. M. Finlayson and D. S. Mitchell*

1. Introduction

The use of aquatic plants for the removal of inorganic nutrients and other pollutants from wastewater has received increasing attention in recent years. This has stemmed, in particular, from attempts to treat industrial and urban effluents in West Germany (16, 21, 22), The Netherlands (5, 17) and the Unites States of America (7, 25, 26). These attempts have differed in terms of the effluents treated and the plant species used. Thus, in Europe the large emergent species *Schoenoplectus lacustries* (Vahl) A. Love and D. Love and *Phragmites australis* (Cav.) Trin. ex Steud. have been widely used while in the USA attention has focussed on the floating plant *Eichhornia crassipes* (Mart.) Solms. These or similar species are common in Australia and have the potential to be included in aquatic plant systems to treat wastewaters in this country.

Mitchell (18) has reviewed the potential for using aquatic plants for this purpose in Australia while Jackson and Gould (14) have investigated the potential of four genera (*Typha, Salvinia, Myriophyllum* and *Spirodela*) and have established a pilot scheme using *Myriophyllum aquaticum* (Velloso) Verde. The potential of *M. aquaticum* and *Cotula coronopifolia* L. are also under investigation as part of an aquaculture system to treat secondary sewage effluent (15). In a pilot system established at Moint Isa, Queensland the floating fern *Salvinia molesta* (D.S. Mitchell) removed large quantities of nutrients and heavy metals from secondary sewage effluent (10). This or a similar system could be important in treating wastewaters in the irrigation areas of south-east Australia where the quality and quantity of water is of major economic importance.

Water quality problems can be caused by water shortage and by water pollution due to effluent discharge to the drainage system (23), which may serve as a water

* Dr. C. M. Finlayson and Dr. D. S. Mitchell, CSIRO Division of Irrigation Research.
Anschrift: Private Mail Bag, Griffith, New South Wales 2680, Australia

supply for farms and urban developments further downstream. Effluents discharged from rural industries such as dairies, wineries, piggeries, rendering plants, abattoirs and also from country town sewage systems can have deleterious effects on the quality of receiving waterways and thus be a major disposal problem. Due to the reported success of aquatic plant filter systems in removing pollutants from point sources, the potential of this method for treating rural effluents has been investigated.

2. Selection of plant species

Plant species for initial investigations were selected on the following criteria (18):

1. Rapid and relatively constant growth
2. Ease of propagation
3. Capacity for absorption of pollutants
4. Tolerance of hyper-eutrophic conditions
5. Ease of harvesting and usefulness of harvested material.

E. crassipes and *S. molesta* appeared obvious choices but they are both introduced noxious weeds (19) not currently found in the irrigation areas, and their introduction to treat wastewaters would be unacceptable. The potential of native plants already established in our irrigation systems and meeting the above criteria has therefore been investigated. Three genera of emergent plants were chosen (*Typha domingensis* Pers. with *T. orientalis* Presl., *Phragmites australis* and *Schoenoplectus validus*) and their ability to treat effluent from a poultry abattoir, a winery and a piggery is being assessed. Native species not known to be present in the irrigation areas that are suitable for inclusion in further investigations are *Eleocharis sphacelata* R. Br. and *Baumea articulata* (R. Br.) S. T. Blake.

3. Ability of the plants to grow in the effluents

Initial works with a piggery effluent demonstrated that *Typha* spp. could not grow in the undiluted effluent but could survive in a 50% dilution (4). The tolerance of *T. Domingensis, T. orientalis* and *S. validus* to the effluents from the piggery, a winery and a poultry abattoir was further tested under glasshouse conditions. *P. australis* was not included in these experiments as it was extremely difficult to propagate plants of uniform size from either seeds or rhizome cuttings. Similar problems with Australian populations of this species were also found by Clucas and Ladiges (3) during a salinity tolerance study. *Typha* spp. and *S. validus* were vegetatively propagated and tested against four concentrations (0, 30, 60 and 100%) of the effluents diluted with irrigation channel water.

The plants could not grow in 30% and above concentrations of winery effluent; all plant replicates died after one week. The piggery effluent was less severe on the plants but at 100% and to a lesser extent at 60% concentration the leaves were severely affected although new shoots and roots were produced. The 30 and 60%

abattoir effluent promoted growth of both *Typha* species (Fig. 1) though in the undilutes effluent less growth occurred. There were no significant differences between the growth responses of *S. validus* (Fig. 1) with all plants accumulating more biomass. In contrast *E. crassipes* and *S. molesta* could not survive in 10% and above concentrations of piggery effluent (24).

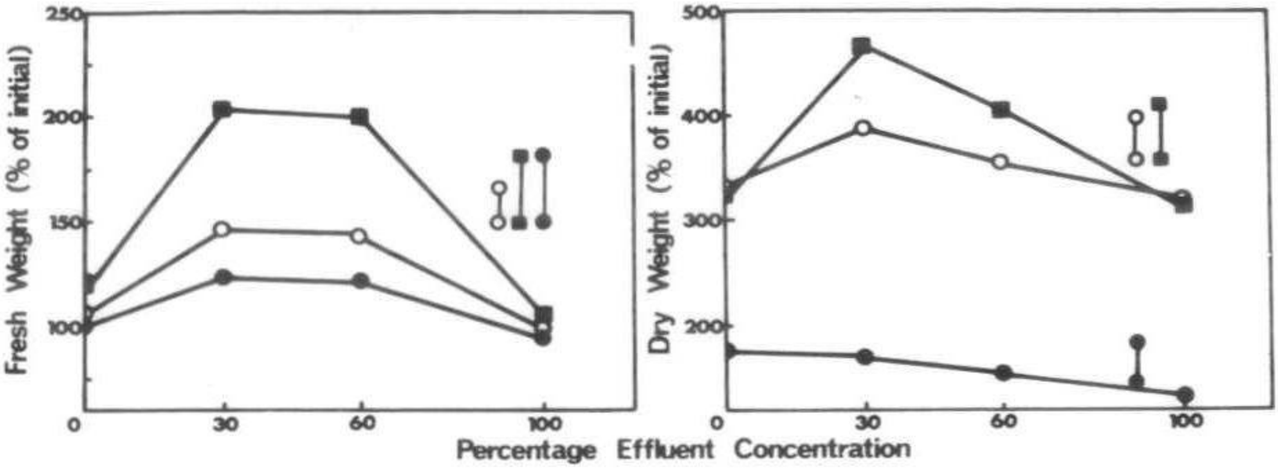

Fig. 1. Fresh and dry weight changes of *Schoenoplectus validus* (●), *Typha orientalis* (○) and *Typha domingensis* (■) grown in effluent from a poultry abattoir. Error bars are LSD values, P = 0.05.

Analyses of the effluents used in these experiments show them to differ greatly in concentration of major cations and anions (Tabelle 1). The abattoir effluent is generally the least concentrated but even it contains high levels of N and P as compared tho those of waters in the local irrigation systems (4). The piggery effluent was more concentrated with a particularly high N content while the winery effluent was characterised by very high K levels. After examination of these analyses and the growth responses of the plants it was decided to investigate their tolereance to NaCl and KCl.

4. Salt tolerance

(4.1) *T. domingensis* and *T. orientalis* plants, collected from populations in the local irrigation area, survived but did not grow in a solution containing 100mM KCl and exhibited only slow growth in 75 mM KCl (8). At 25 mM KCl *T. orientalis* grew better than *T. domingensis* which suggests that in an effluent containing this concentration of KCl the former would grow better, assuming other components of the effluent did not interfere. Hocking (12) found, over an 8 week period, that growth of *T. domingensis* was reduced by NaCl between 50 and 75 mM; a value slightly lower than the 85 mM reported by Anderson (1) to kill *T. latifolia*. From the KCl and NaCl results the two local species appear to be moderately salt tolerant.

The poor growth of *T. orientalis* in the KCl experiments was probably due to Cl but a similar conclusion could not be drawn from the *T. domingensis* results. In the *T. domingensis* NaCl experiment, however, Cl was suggested as being responsible for the poor growth responses (12). Synergistic effects may also occur and the ionic balance may also affect tolerance. Further work is required to obtain a better understanding of the role these ions play in the growth of *Typha* spp. and both salts are to be combined in a future experiment.

Table 1. Mean concentration and 95% confidence limits (in brackets) of major ions and nutrients in effluents from an abattoir, a piggery and a winery

Effluent	Na	K	Cl	Total P	Kjeldahl N	pH	n*	Dates
	meq/l			mg/l				
Abattoir	1,50 (0,51)	0,84 (0,20)	3,51 (0,73)	15,1 (3,1)	139 (29)	6,6 (0,2)	10	Aug 80–Jan 81
Piggery	10,12 (2,14)	31,83 (3,37)	26,00 (3,86)	174,5 (24,9)	2014 (135)	8,2 (0,1)	12	May 80–Oct 80
Winery	6,02 (0,78)	198,33 (42,38)	8,67 (0,56)	345,0 (60,8)	487 (86)	5,5**	3	March 81

* Number of samples collected
** Only one analysis carried out

The K and Cl in the piggery effluent (Table 1) could affect the growth of both species but not severely. In contrast the winery effluent contained K (Table 1) well in excess of the tolereance level for KCl (8).
(4.2) *S. validus* was not adversely affected by NaCl concentrations between O and 100 mM. A second experiment extending the NaCl concentration to 250 mM

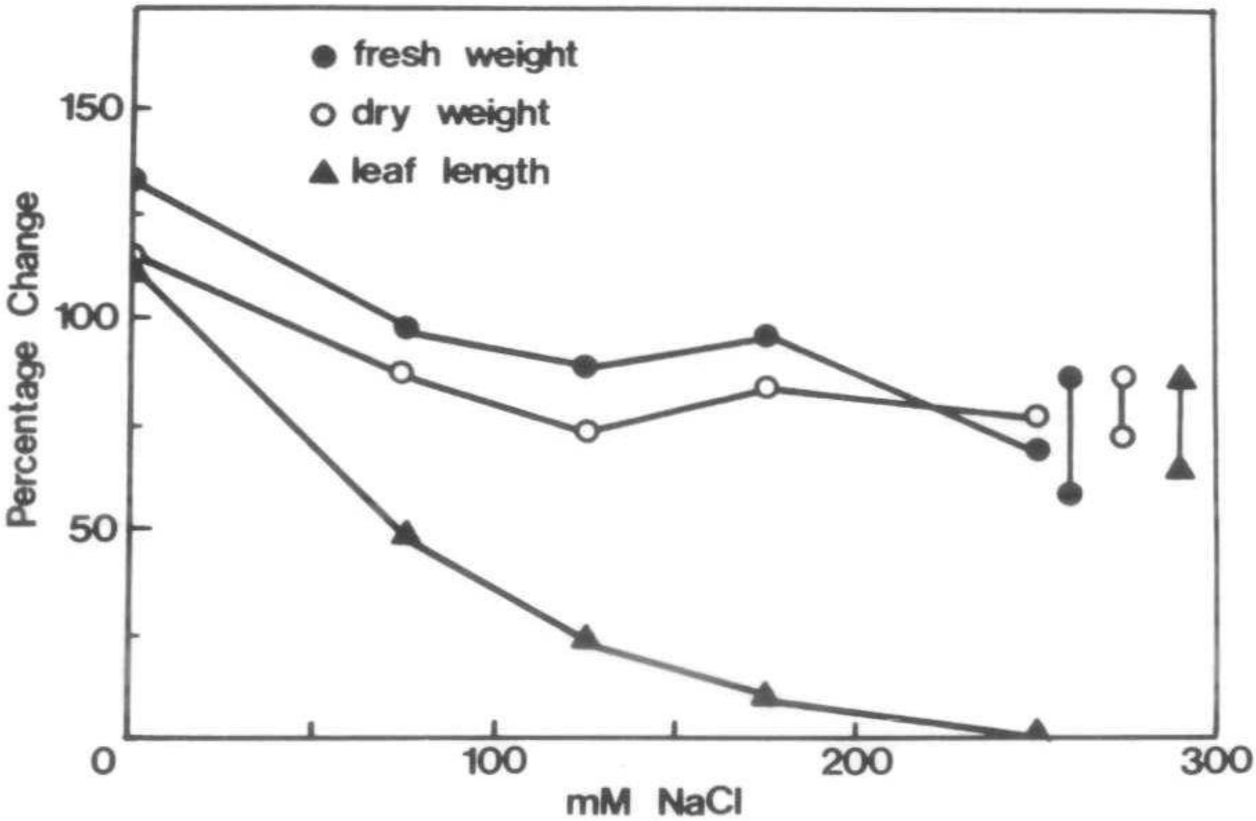

Fig. 2. Fresh weight (●), dry weight (○) and leaf length (▲) responses of *Schoenoplectus validus* to NaCl. Error bars are LSD values, P = 0.05.

showed significant growth reductions between 0 and 75 mM NaCl (Fig. 2). The results of these experiments make it difficult to determine the NaCl tolerance level of *S. validus.* Although tolerance may differ seasonally it is likely to be in the vicinity of 75–100 mM NaCl, a value similar to that for the locally collected *T. domingensis* (12). With this level of tolerance the salt content of the piggery effluent on its own should not have had a severe effect on the plants. However, both *S. validus* and *Typha* spp. were severely inhibited, suggesting that other substances in the effluent were restricting growth of the plants.

(4.3) *P. australis* was not included in these experiments but it has a well documented salinity tolerance. Under experimental conditions it can survive at more than 35 g/kg total salinity but in field conditions is usually restricted to less than 20 g/kg (11, 20), while around the Gippsland Lakes in southern Australia it is restricted to areas of less than 12 g/kg (2). This latter value corresponds to about 160 mM Na and 190 mM Cl, levels well in excess of those tolerated by the locally collected *Typha* spp. and *S. validus*.

(4.4) As the winery effluent contained more K than levels tolerated by *Typha* spp. and *S. validus*, further experiments were done to determine if plants collected from saline areas had developed salt-tolerant-ecotypic differences. The wide and varied distribution of *Typha* spp. throughout Australia suggests that these species may have evolved a genetic potential to tolerate high salt levels. Plant species not innately tolerant to a particular substance have the capacity to achieve greater levels of tolerance by the development of tolerant – ecotypes (13). This certainly apperars to be so for *T. domingensis* with some seedling populations capable of growing in 150-175 mM NaCl (24). Similarly plants grown from rhizomes have been shown to have a NaCl and KCl tolerance in excess of the 75 mM tolerated by *Typha* used in the previous experiments. Unlike the latter, however, many of the ecotype populations did not have a similar response to NaCl and KCl. As salinity effects are due to a number of different salts this is one aspect that clearly requires closer attention if effluents with high salinity are to be treated by aquatic plants.

The possibility of using these ecotype populations is largely dependent on the ease with which they can be collected, transported and propagated at the treatment site. *Typha* is easily grown from seeds and is therefore relatively easy to handle. By contrast, any salt-tolerant-ecotypes of *P. australis* that were found, would be more difficult to establish in different parts of Australia as this species has a low proportion of viable seeds (3). Such problems could be overcome by establishing techniques for germinating seeds of species that are selected for inclusion in aquatic plant treatment systems.

5. Experimental aquatic plant filter systems

Three expertimental systems have been established to investigate the ability of aquatic plant filters to remove pollutants from rural wastewaters. The first was constructed at a poultry abattoir that discharged 30 000 – 50 000 l of effluent („blood-water") each working day. Due to economic conditions this enterprise closed down shortly after the system was sufficiently well established for experimental work to begin. Sampling was consequently reduced to a relatively short period. The second system was established at an intensive feedlot piggery that houses 4 700 pigs and discharges 40 000 l of effluent daily. The third and largest system was near a rendering plant that daily discharges 112 000 l of effluent to an evaporation pond that can also receive a maximum of 22 500 l of effluent from a poultry abattoir. The operation and effectiveness of the three experimental systems is described below.

(5.1) Three trenches 1,8 m wide, with two being 20m and the third 15m long were constructed at the abattoir (Fig. 3). They were lined with black plastic and filled with 20mm gravel to a depth of 0.5m. Effluent was pumped from an uncovered storage tank to one end of each trench and allowed to percolate to an outlet pipe at the other end. Water levels were kept below the surface of the gravel and the flow adjusted to provide theoretical retention times of between 2,6–3,6 days for each trench. The three trenches were planted separately with *Typha* spp., *P. australis* and *S. validus* in order to compare the effectiveness of these genera. The plants were left for 7 months before sampling started.

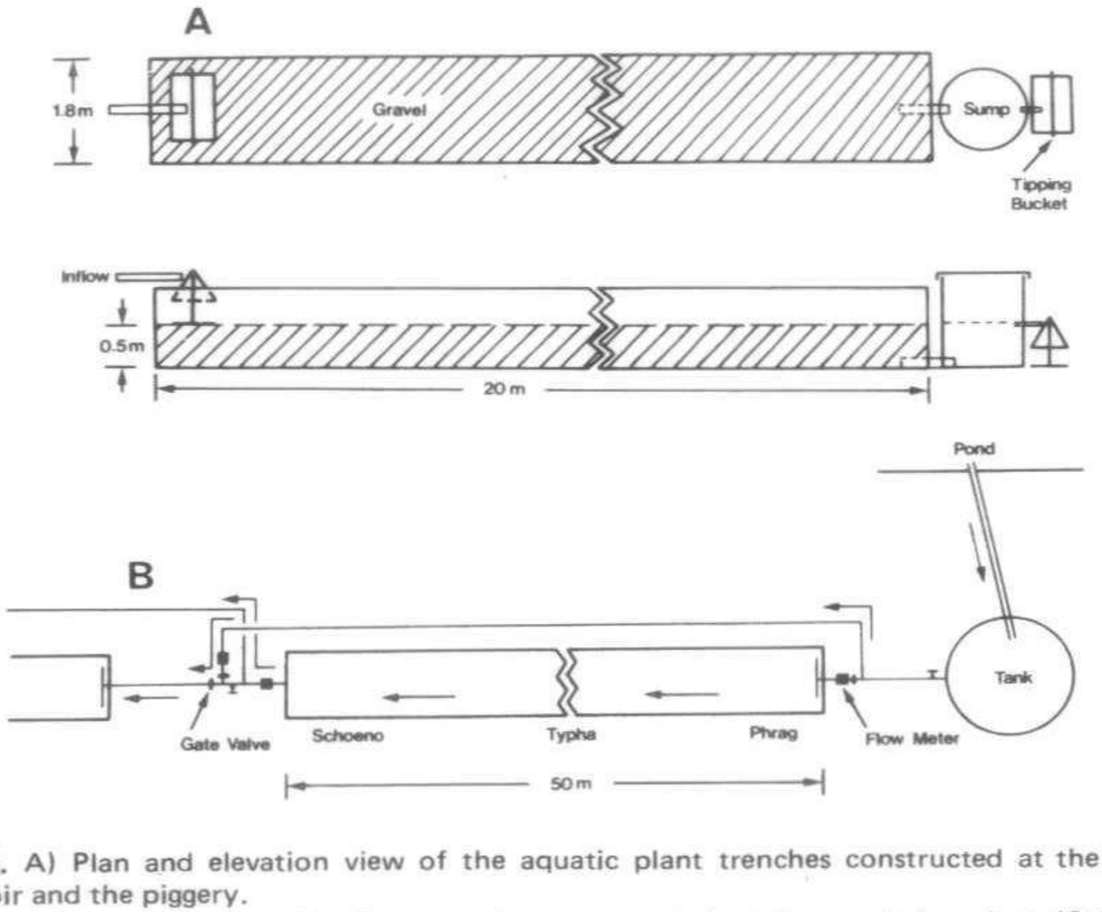

Fig. 3. A) Plan and elevation view of the aquatic plant trenches constructed at the poultry abattoir and the piggery.
B) Plan view of the aquatic plant trenches constructed at the rendering plant (*Schoeno = Schoenoplectus validus, Typha = Typha* spp., *Phrag. = Phragmites australis*).

Effluent samples were collected on 17 occasions over a one month period during autumn 1981 (9). Suspended solids (80–90%) and turbidity (60–70%) were removed from the effluent in each trench, resulting in a much clearer liquid that generally met the State Pollution Control Commission's discharge standard of

30 mg/l suspended solids. A marked advantage conferred by the *P. australis* and *S. validus* systems was oxygenation of the anaerobic inflow. The nitrogen and phosphorus removal, taking into account a 30–50% loss of water by evapotranspiration, was much greater in the *S. validus* trench (Table 2). Nutrient removal in the trenches could be due to filtering of organic particles by the gravel, resulting in accumulation in the trench or decomposition and recycling, especially of the nitrogen. The *S. validus* trench had a marked decrease in ammonia-nitrogen (34–15 mg/l) and an increase in nitrate-nitrogen (80–2760 µg/l), though nitrate only comprised 6% of the nitrogen in the outflow (compared to 0,08% in the inflow).

Table 2. Comparison of the total amount of nitrogen and phosphorus contained in the inflow and outflow of the three aquatic plant filters over the experimental period. The percentage changes are shown in brackets

Nutrient	Trench System					
	Typha		*Phragmites*		*Schoenoplectus*	
	In	Out	In	Out	In	Out
Total nitrogen (g)	1553	901	1564	589	1040	270
	(–42%)		(–62%)		(–74%)	
Total phosphorus (g)	228	74	230	74	155	33
	(–68%)		(–68%)		(–79%)	

The substantial nutrient decreases show that the plants and microbial populations, in conjunction with filtering through the gravel are successful in treating the effluent. The long-term effectiveness of the system is a matter for speculation but similar systems in the Netherlands have a life in excess of 14 years (6). A prime objective of our future work ist to determine the longer-term efficiency of these trench systems.

A decrease in tissue nitrogen and phosphorus contents and slow growth rates of *Typha* spp. and *S. validus* suggests that the plants are not an important nutrient sink so that harvesting them would not remove al large quantity of nutrient from the system. Similarly *P. australis* had a decrease in tissue nutrients, but had much faster growth rates, thus increasing the feasibility of nutrient removal by harvesting. This is another aspect that needs further investigation over a longer time period. While harvesting the plants does not appear to be a promising method for nutrient removal, the plants are important in these treatment systems as they oxygenate the substrate and support an active rhizosphere microbial population (5, 6).

While more information is required about the functioning of these aquatic plant filter systems the results of a one month investigation (9) established their potential for treating abattoir effluent.

(5.2) The experimental facility at the piggery consisted of two 20 m trenches of the same design as those used at the abattoir (Fig. 3). They were planted with Typha spp. and some *S. validus* and left for 12 months before sampling started. The concentrated effluent was diluted to approximately 25% (conductivity 2 500 µS/cm at 25°C) and added to the trenches with a theoretical retention time of 5 days. Diluting the effluent is obviously contrary to the eventual aim of direct removal of pollutants from the raw effluent and then recycling the water, but at this early stage it was necessary to avoid killing the plants.

Table 3. Comparison of the mean values and 95% confidence limits (in brackets) for the inflow and outflow analyses from two aquatic plant filters at the piggery. The mean values were obtained from 12 samples collected during March–May 1982

	I				II			
	In		Out		In		Out	
Suspended solids (mg/l)	220	(78)	88	(55)	210	(76)	80	(59)
Turbidity (NTU)	68	(18)	36	(5)	45	(7)	39	(6)
pH	7,9	(0,2)	7,8	(0,2)	8,9	(0,1)	7,9	(0,2)
Conductivity (25°) (μS/cm)	2665	(684)	2100	(602)	2634	(751)	2146	(580)
COD (mg/l)	567	(80)	349	(100)	538	(67)	354	(82)
NH_3-N (mg/l)	991	(112)	797	(237)	961	(163)	753	(249)

An indication of the ability of the trench systems to remove pollutants from the piggery effluent can be obtained from Table 3. The suspended solids were reduced as the effluent flowed through the trenches but the turbidity was reduced in only one trench. Conductivity was not substantially different but due to an estimated 30–40% loss of water by evapotranspiration the amount of salt in the effluent outflow should be less than that added to the trenches. The organic material in the effluent was being efficiently removed but under the anaerobic conditions removal of ammonia-nitrogen was not substantial. The continuing sampling program should give a much better understanding of the ability of these systems to treat the piggery effluent.

(5.3) The treatment system at the rendering plant consists of two 50 × 2,5m trenches with gravel to a depth of 0,5m (Fig. 3). The first 10m of each trench consists of 5mm gravel and the rest 20mm gravel. These trenches were lined with a durable rubber material; a liner is important in the experimental systems if nutrient mass balances are to be calculated. The three genera being investigated were planted in each trench (Fig. 3). When the plants have established and the system is fully operational it is planned to investigate the mechanisms by which the plant and microbial population contribute to the treatment process. A trench without plants is also being established to determine the effectiveness of the gravel in the removal of pollutants.

Effluent is being supplied to the systems while the plant populations are establishing. Sampling has not started but it is already obvious that with a 5 day retention time the high chlorophyll content of the inflow is being substantially reduced. As algae can be a major contributor to suspended solids and biochemical oxygen demand in an effluent, it can be assumed that they are also being reduced. A second observation has been the reduced plant growth with distance from the inflow, possibly by nutrient depletion in the first section of the trench.

Both observations will be investigated as part of the long-term study into the efficiency of these aquatic plant filters.

6. Summary

Four Australian species of emergent aquatic plants (*Typha domingensis, T. orientalis, Phragmites australis* and *Schoenoplectus validus*) were chosen and their ability to treat rural wastewaters, exemplified by effluents from abattoirs, piggeries and

wineries, was investigated. Glasshouse experiments demonstrated that the plants could grow in the abattoir effluent but not in the undiluted piggery and winery effluents. The salt levels in these effluents were high and thought to be responsible for the poor growth. However, further glasshouse experiments showed that ecotypic populations of *Typha* spp. could survive at these levels. The dilemma that this raises is being further investigated.
An experimental facility at a poultry abattoir showed that over a short-term the aquatic plant filters could satisfactorly remove pollutants from the effluent. Large amounts of suspended solids, nitrogen and phosphorous were removed by the trenches. The systems containing *P. australis* and *S. validus* oxygenated the anaerobic inflow. The role of the plants in the treatment process is not clear though harvesting to remove nutrients from the system does not appear worthwile. Preliminary results from the experimental facility at the intensive piggery indicate that this system is likely to be much less efficent than that at the poultry abattoir. A third system at a rendering plant is nearing completion and should enable longer-term studies on the treatment process to be carried out.

Zusammenfassung

Die vorliegende Arbeit stellt eine Zusammenfassung der in Australien unternommenen Versuche zur Nutzung von aquatischen Pflanzen bei der Behandlung ländlicher Abwässer dar. In die Untersuchungen einbezogen wurden vier australische Spezies (Typha domingensis, T. orientalis, Phragmites australis und Schoenoplectus validus). Die Eignung dieser Pflanzen für das Limnologische Klärverfahren (auch Wurzelraumentsorgung genannt) wurde untersucht mit Abwässern aus der Schweinehaltung, der Weinbereitung und der Geflügelschlachterei. Gewächshausversuche zeigten, daß die obigen Pflanzen in unverdünnten Abwässern aus Geflügelschlachtereien, aber nicht in solchen aus der Schweinehaltung und der Weinbereitung wachsen können. Die Salzkonzentrationen der letzten beiden Abwässer waren hoch und wurden zunächst als Ursache für das geringe Wachstum angesehen. Weitere Versuche zeigten, daß spezielle Ökotypen von Thypa spp. durchaus auch unter solch hohen Konzentrationen überleben. Der sich daraus ergebende Fragenkomplex wird z. Zt. näher untersucht.
Eine Versuchseinrichtung bei einer Geflügelschlachterei zeigte, daß mittels der Wurzelraumentsorgung in relativ kurzer Zeit eine begriedigende Entfernung der Schmutzstoffe erfolgt. Große Mengen suspendierter Feststoffe, Stickstoff und Phosphat wurden mittels dieses Limnologischen Klärverfahrens aus dem Abwasser entfernt. Die Rolle der Pflanzen im Rahmen dieses Klärverfahrens ist noch nicht in allen Einzelheiten klar erkannt, insbesondere da das laufende Abernten der Pflanzen als nicht lohnend angesehen wird.
Die vorläufigen Untersuchungsergebnisse aus Versuchen im Rahmen eines intensiven Schweinehaltungsbetriebes zeigen, daß die Wurzelraumentsorgung wahrscheinlich sehr viel weniger effizient ist als bei der Behandlung der Abwässer aus einer Geflügelschlachterei.
Eine dritte Versuchsanlage befindet sich kurz vor der Fertigstellung. Sie soll einen Langzeitversuch zur Untersuchung der noch offenen Fragen der Wurzelraumentsorgung ländlicher Abwässer ermöglichen.

References

1. ANDERSON, C. M., 1977: Cattail decline at Farrington Bay waterfowl management area. – Great Basin Nat. 37, 24–34.

2. BIRD, E. D. F., 1978: The geomorphology of the Gippsland Lakes. – Publication No. 186 Environmental Study Series, Ministry for Conservation, Victoria, Australia.

3. CLUCAS, R. D. and LADIGES, P. Y., 1980: Die-back of *Phragmites australis* (common reed) and increased salinity in the Gippsland Lakes. – Publication No. 92 Environmental Studies Series, Ministry for Conservation, Victoria, Australia.

4. CSIRO, 1980: Division of Irrigation Research 1978–80 Report. – CSIRO, Griffith, Australia.

5. De JONG, J., 1976: The purification of wastewater with the aid of rush or reed ponds. In: Tourbier, J. and Pierson, R. w. (eds), 1976: Biological Control of Water Pollution. University of Pennsylvania Press, USA.

6. De JONG, J., KOK, T. and KORIDON, A. H., 1977: The purification of sewage with the aid of ponds containing bulrushes or reeds in the Netherlands. – Rijp Rapport, Rijksdienst voor de Ijsselmeerpolders Smedinghuis, Lelystad, The Netherlands.

7. DINGES, R., 1976: Water hyacinth culture for wastewater treatment. – Texas Department of Health Resources, Division of Wastewater Technology and Surveillance. Austin, Texas, USA.

8. FINLAYSON, C. M., 1982: The response of *Typha domingensis* and *Typha orientalis* to high levels of KCl. – Aquat. Bot. (submitted).

9. FINALYSON, C. M. and CHICK, A. J., 1982: Testing the potential of aquatic plants to treat abattoir effluent. – Water Res. (In press).

10. FINALYSON, C. M., FARRELL, T. P. and GRIFFITHS, D. J., 1982: Treatment of sewage effluent using the water fern salvinia. – Water Research Foundation of Australia, Technical Report No. 57.

11. HASLAM, S. M., 1973: Some aspects of the life history and autecology of *Phragmites communis* Trin. A Review. – Pol. Arch. Hydrobiol. 20. 79–100.

12. HOCKING, P. J., 1981: The response of *Typha domingensis* to salinity and high levels of manganese in the rooting medium. – Aust. J. Mar. Freshwater Res. 32, 907–919.

13. HUMPHREY, M. D. and BRADSHAW, A. D., 1976: Genetic potentials for solving problems of soil mineral stress: Heavy metal toxicities. In: Wright, M. J. and Ferrari, S. A. (eds): Plant adaptation to Mineral Stress in Problem Soils. Cornell University, USA.

14. JACKSON, J. D. and GOULD, B. W., 1981: Sewage treatment with water weeds. – Proc. Australian Water and Wastewater Association 1981 National Conference, Perth, Australia May 1981.

15. KERR, R., 1981: Personal communication. – Dandenong Valley Authority, Melbourne, Australia.

16. KICKUTH, R., 1975: Degradation and incorporation of nutrients from rural wastewaters by plant rhizosphere under limnic conditions. – Utilisation of Manure by Land Spreading, Co-orditation of Agricultural Research, Commission of the European Communites.

17. KOK, T., 1974: De reiniging van advalwater van een kampeerterrain met behulp van een biezenveld. – H_2O 7, 537–544.

18. MITCHELL, D. S., 1978: The potential for wastewater treatment by aquatic plants in Australia. – Water (Melb.) 5, 15–17

19. MITCHELL, D. S., 1978: Aquatic weeds in Australian Inland Waters. – Aust. Govt. Publ. Service, Canberra, Australia.

20. RANWELL, D. S., BIRD, E. C. F., HUBBARD, J. C. E. and STEBBINGS, R. E., 1964: Spartina salt marshes in southern England. V. Tidal submergence and chlorinity at Poole Harbour. – J. Ecol. 52, 627–642.

21. SEIDEL, K., 1976: Macrophytes and water purification. In: Tourbier, J. and Pierson, R. W. (eds), 1976: Biological Control of Water Pollution. University of Pennsylvania Press, USA.

22. SEIDEL, K., HAPPEL, H. and GRAUE, G., 1978: Contributions to revitalisation of water. – Stiftung Limnologische Arbeitsgruppe Dr. Seidel c. v., Meersburg, West Germany.

23. State Pollution Control Commission, 1979: Annual Report for the year ending 30 June 1979. – New South Wales Gobernment, Sydney, Australia.

24. VON OERTZEN, I. A., 1981: Use of Different Water plants in Biological Filter Systems for the Treatment of Agricultural Wastewaters. – B. Ag. Sc. Thesis, Rheinische Friedrich-Willhelms Universität, Bonn, West Germany.

25. WOLVERTON, B. C. and McDONALD, R. C., 1975: Water hyacinths for upgrading sewage lagoons to meet advanced wastewater treatment standards, Part 1. – NASA Technical Memorandum X–72722.

26. WOLVERTON, B. C. and McDONALD, R. C., 1975: Water hyacinths and alligator weeds for removal of lead and mercury from polluted waters. – NASA Technical Memorandum X–72723.