Forum

The Algal Bloom Problem In Australian Waterways: an Economic Appraisal

Gamini Herath*

This paper discusses algal blooms in waterways from an externality perspective. Algal activity is directly related to phosphorus intake, but this can vary by season and by degree of dilution. Policy alternatives, including property rights, taxes, tradeable permits and water pricing are discussed. Issues relating to detergent control and technological approaches are presented.

1. Introduction

Algal blooms have become an important water quality problem in many countries in the world including Australia (Jones; Morse, Lester and Perry)[1]. They are primarily caused by the excessive availability of nutrients, phosphorus in particular, which originate from sewage treatment works, animal farms, and heavily fertilised agricultural land. The algae are found in water at various depths, and under favourable conditions, appear suddenly at the surface in abundance, creating a bloom. The world's largest algal bloom occurred in Australia in December 1991, where 1000km of the Darling-Barwon River was affected (Department of Water Resources). In Australia, the most severe blooms have occurred in the states of New South Wales (NSW) and Victoria (Murray Darling Basin Commission 1994).

Algal toxins in water can cause serious health problems for wildlife, livestock and pets. Fatalities among these due to algal toxins have been reported in many parts of the world (Morse *et al.*). The 1991 bloom caused a loss of one million people-days of drinking water. Direct costs incurred, through increased water treatment and the provision of alternative water supplies, were more than $1.3m (Murray Darling Basin Commission 1994). Algal blooms can also cause amenity problems due to loss of clear water for recreation. Several recreational sites in Victoria and interstate have had to be closed to users in recent times. During the 1991 bloom there were losses of about 2000 site-days of recreation. The losses in sections of the Nepean - Hawkesbury River, Darling River and Department of Water Resources Storages in 1991 were valued at around $10m (Walker and Greer[2]). These include the direct recreational losses experienced by the users of the waters, and the losses associated with commercial activities such as provision of accommodation, transport, food, caravan and tourist parks.

Many public institutions have identified the algal bloom problem as a key water quality problem in Australia, a view shared by the states as well as the Federal Government. A Blue-Green Algae Task Force (BGATF) was appointed by the NSW Government in 1991 to examine all aspects of the problem[3]. It recommended several economic, technological and institutional changes. However, algal problems, in particular the relationship between farm decisions and algal blooms have received relatively little economic analysis. The impact of agricultural land use on algal blooms raises important issues for economic policy, involving the incentives that lead farmers to adopt different management techniques and how institutional practices operate to generate these incentives.

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* La Trobe University, Albury-Wodonga Campus.

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[1] Algal blooms have been a serious problem in countries such as Denmark, Belgium, Germany, Italy, the Netherlands, Greece, Ireland, Luxembourg, Spain as well as USA and Canada (Jones; Morse, *et al.*). Throughout this paper the algae referred to are the blue-green algae.

[2] The losses of recreational activities may be reduced using substitute sites. In cases where substitute sites are not available in close proximity or the algal blooms strike a wide area, such cost reduction may not be high.

[3] The Blue-Green Algae Task Force (BGATF) had 13 members in the committee, drawn from a number of disciplines with a view to obtaining policy guidelines to solve the algal bloom problem. The final report of the BGATF was completed in 1992.

The objectives of this paper are to examine:

1. the economic factors which influence algal blooms in Australian waterways;

2. how different institutional structures, technological changes and government policies can affect algal blooms through their impact on land use; and

3. the effectiveness of alternative economic instruments to address this problem.

The structure of the paper is as follows. The first section provides the background of algal blooms in Australia. Section two sets out the externality nature of algal blooms. The third section discusses non-point phosphorus pollution in Australian waterways and, in particular, how the nature of technological change and government policies in agriculture have exacerbated nutrient pollution. The fourth section examines point phosphorus pollution from sewage plants and the role of detergents. Section five presents a discussion of how the cheap water policy assisted the nutrient pollution process. Section six examines the potential and problems of some of the common economic instruments such as property rights, efficient water pricing, Pigouvian taxes, and tradeable permits in controlling algal blooms. Section seven examines issues relating to detergent phosphorus and technological change in sewage disposal. The last section concludes the paper with some policy directions to mitigate the algal bloom problem in Australia.

2. Externalities and Algal Blooms

An externality is an uncompensated cost or benefit imposed upon another person's production or consumption. In simple terms, externalities can be expressed by making the utility and production functions dependent on the activities of other agents. Formally, if u_i represents the utility function of the i^{th} consumer, and x_1, x_2, x_3,... purchases of goods and services by this consumer

(1) $u_i = f(x_1, x_2, x_3, .., z_1, z_2)$

where z_1 and z_2 are the activities of others. Similarly the profit function p_i of a producer may be a function both of its own purchases of inputs y_1, y_2, y_3 and of the activities of other agents z_1 and z_2, ie.

(2) $p_i = f(y_1, y_2, y_3, .., z_1, z_2)$.

In the context of the above formulation, z_1 and z_2 can be thought of as environmental pollutants or as factors of production. A reduction of z_1 and z_2 results in reduced output or utility because cut-backs on pollutants require the diversion of other inputs thereby reducing the availability of these factors for production of goods. In general, market equilibria will be Pareto inefficient in the presence of externalities (Varian 1992). This implies that private costs and returns do not accurately reflect social costs and returns as market prices are not true indicators of social scarcity values[4]. As a result, producers can produce too much or too little so that the market outcome is inefficient from a social point of view.

The algal bloom problem fits into this externality framework. Disposals of treated sewage effluent and run-off from pasture, forests and agriculture are the major sources of phosphorus pollution. Such upstream phosphorus affects downstream water users. Thus those affected by algal blooms are separated from the polluters. Consequently, the costs of algal blooms are borne by the affected groups, who in the absence of a market are not compensated by the polluters. The genesis of the externality can be traced to the absence of clearly defined property rights to the water. In these circumstances, if exclusion is technologically infeasible or too costly relative to the potential gains, there will be unrestricted access to water, creating water quality problems.

While absence of markets and lack of compensation adequately establishes the externality nature of algal blooms, there are other characteristics that provide insights into the difficulties of controlling algal blooms. Stewart and Ghani consider five such attributes of an externality, namely, the nature of the interacting agent, number of agents involved, salience of the externality, economic status of the affected groups and their location. The relevance of these to the algal bloom problem is briefly explored below.

The nature of the interacting agent is the distinction between the producers and the consumers. The algal bloom problem can, in principle, occur in four ways; namely, from producers to producers, producers to consumers, consumers to consumers, and consumers to producers. The most significant type of relation-

4 Pareto efficiency refers to the most efficient allocation of resources where the incentives for further voluntary trade are exhausted.

ship for algal blooms is the producer-consumer interaction. While "many to many"interaction is the dominant form for non-point pollution, point source pollution from sewage plants also involves many affected groups and few polluters.

The salience of the externality too has implications for its control. The algal bloom problem is initially not very visible. The bright green colour and the odour are often late symptoms. The blooms can reach a climax weeks prior to becoming visible. The slow nutrient enrichment of Australian waterways does not evoke an immediate response. It is only when algal blooms strike that the problem is deemed important. The neglect of this problem in the past reflects this lack of salience.

The economic status of the polluters and the affected groups reflects a political power balance. The polluters such as farmers and sewage authorities are in a strong bargaining position both politically and legally. Many past policies created incentives for farmers and the environment was the loser. The spatial location of the polluters and those affected also determines rapidity of control. Algal blooms can occur across long stretches of water. Those affected are highly dispersed and heterogeneous, and co-ordinated action by them is difficult.

3. Algal Blooms and Non-point Source Nutrients[5]

There is increasing recognition that expansion of agriculture in Australia aided by support policies such as input subsidies, water subsidies and price support has contributed to nutrient pollution (Table 1). Phosphorus in water has increased by about 5 per cent per year in recent years. Analysis of 18 years of data on nutrients in water by the Department of Water Resources shows that median levels of phosphorus exceed 0.05 mg/l in all Western Basins. The phosphorus losses from agriculture to rivers, lakes, wetlands and reservoirs in Australia are estimated to be about 25000 tonnes per annum (Creagh). The Hawkesbury River now receives some 30 tonnes of phosphorus per year from urban run-off and 130 tonnes of phosphorus per

[5] In non-point nutrients there is no indication as to where the nutrients originate and the nutrient dynamics cannot be easily monitored.

Table 1: Summary of Non-Point Source Nutrient Loads in the Murray-Darling Basin

Land use category	Nutrient (t/yr) Dry year TP	Dry year TN	Av. year TP	Av. year TN	Wet year TP	Wet year TN
Murray-Murrumbidgee Basin						
Forest	35	700	180	3,600	550	11,000
Pasture	50	225	220	1,100	600	3,000
Crops	15	75	100	150	250	400
Total	95	1,000	500	4,850	1,400	14,400
Darling Basin:						
Forest	10	200	40	800	300	6,000
Pasture	45	225	140	700	950	4,800
Crops	95	145	260	390	1,600	2,400
Total	150	570	440	1,890	2,850	13,200
Overall Total*	250	1,570	940	6,740	4,250	2,760

TP= total phosphorus, TN= total nitrogen

* Assuming that "dry", "average", and "wet" conditions occur in the same year in both the Darling and Murray-Murrumbidgee Basins.

Source: Murray-Darling Basin Commission, 1992 year from rural run-off. This is a total of about 160 tonnes/year in an average year which can rise in a wet year to around 300 tonnes (Environmental Protection Authority NSW). In recent years droughts, high temperatures, and river flows reduced by water withdrawals for irrigation have caused increased algal growth. During wet weather, especially during floods, most of it originates from agricultural lands and forests (Murray Darling Basin Commission 1992).

3.1 Technical Change in Agriculture

Productivity growth in Australian agriculture due to technological change has risen at an average annual rate of around 2.2 per cent per year over the 17-year period to 1988/89 (Males, Davidson, Knopke, Lonka, and Roarty). The nature of technical change depends on a variety of institutional and public policy factors and on the relative prices of inputs. High labour costs led to labour-saving technological change. Agricultural production increased despite a one third reduction of the agricultural labour force since the 1950s through substitution of capital for labour (Balderstone, Duthie, Jarret, Eckersley and NcColl). The capital-labour ratios have increased by 4 per cent a year in the pastoral zone and by 6 per cent in the wheat-sheep zone (Paul).

Biological technologies such as legume pastures, and high yielding and disease resistant wheat varieties are some of the innovations that have been adopted. Wheat yields in Australia increased during the 1950-90 period, in spite of cropping being extended to some marginal lands. This reflected improvements in plant breeding and machinery, better planting methods and particularly, changes in fertiliser use. Rapid increase in agro-chemical and fertiliser use can be fostered by a decline in their relative prices (Larson and Knudson). Intensive livestock industries were also a source of phosphorus. The feedlots located along the Murray River, which number about 260, deliver some 1650 tonnes of phosphorus per year into the water, and piggeries another 2530 tonnes. These industries are expected to grow in the future (Young, Gomboso and Howes).

3.2 Phosphorus Use

Australian soils are generally deficient in phosphorus, and phosphatic fertilisers have played a significant role in agriculture. Recent phosphate use in Australia shows two clearly discernible periods. The period 1950 to 1963 was an era of rapid increase in the area under crops and pastures which grew at about 5.4 per cent per year and phosphate use increased proportionately. However, despite variation in the real price of phosphate fertilisers, application rates remained stable (Costin and Williams)[6]. After 1963, the phosphate bounty was introduced which stimulated its use. After 1988, when the bounty was withdrawn, phosphate use showed a marked decline. Up to 1988, phosphate use was extensive and in 1979-80 over 12 m. hectares of sown and native pastures were fertilised with 147,449 tonnes of phosphorus. Approximately the same area of cereals and other crops received a further 125,617 tonnes of phosphorus (Blair).

4. Algal Blooms and Point Source Nutrients

Sewage treatment plants are the major point sources of both nitrogen and phosphorus in the rivers of the Murray Darling Basin and other waterways. In dry conditions, most of the nutrients originate from sewage treatment works. The use of detergents has led to an increase in the phosphorus concentration in raw sewage. About 55 per cent of the sewage phosphorus come from detergents and other cleaning agents (Department of Water Resources).

Table 2 provides a summary of municipal sewage plants in the Murray-Darling Basin. Treated effluent from nearly 340,000 people, or 65 per cent of the 520,000 population in the catchment in NSW, is discharged into rivers and streams. Nitrogen reduction is carried out in 34 of the 141 plants but only three plants, serving a total of 60,000 people, provide both nitrogen and phosphorus reduction. Table 3 gives information on nutrient contributions from point and non-point sources in the Murray Darling Basin, which highlights the variability of phosphorus sources with changes in the weather. The point to non-point ratio falls both for phosphorus and nitrogen with wet weather.

6 The estimated elasticities have been in the range 0.2 to 0.6 (Gargett).

Table 2: Summary of NSW Municipal Sewage Treatment Plants in the Murray-Darling Basin

Population Centre size (residential)	Up to 10,000	10,001 to 20,000	20,001 to 30,000	More than 30,000	Total
No. of plants:	131	2	5	3	141
No of plants discharging to streams:	61	2	4	2	69
No. with nutrient removal:					
- nitrogen	28	1	3	2	34
- phosphorous	1	-	1	1	3
- both	1	-	1	1	3
Total population involved:	141,200	23,000	98,000	74,700	338,500

Source: Murray-Darling Basin Commission, 1992

Table 3: Total Point and Non-Point Source Nutrient Inputs to Streams in the Murray Darling Basin

	Nutrient loads (t/yr)*					
Category	Dry Year		Average Year		Wet Year	
	TP	TN	TP	TN	TP	TN
Point sources	650	3900	750	4400	900	5300
Non-point sources	250	1570	940	6740	4250	2760
Point/non-point ratio	2.6	2.5	0.8	0.7	0.2	0.2

* Values generally rounded.

Source: Murray - Darling Basin Commission, 1992

5. Institutional Rigidities and Inefficient Pricing of Water

In general, regulatory rather than market approaches have been adopted for water allocation in Australia. In 1991, the level of subsidisation of irrigation in the Murray Darling Basin was of the order of $300 m. In NSW, where there is no dam or public capital investment, users of unregulated water had to pay only a licence fee which ranged from $103 to $800 for a five year period. The Department of Water Resources enforces a licence fee for irrigation water use in the Hawkesbury-Nepean River. This is based on a sliding scale related to the area irrigated with a maximum of $83 per annum. There are no volume based charges. With a flat fee the marginal cost of additional water is zero and the farmers do not face the true cost of water. Where charges depended on volume, the price of water was $3.50 for a mega litre though the actual costs are about $40.00 a mega litre (Economic Planning Advisory Council). Given this low price for irrigation water, intensive irrigation practices were adopted (Environmental Protection Authority NSW).

Water charges for urban water use are very similar. They contain a substantial cross subsidy from commercial users to domestic users (Table 4). Further, they rely on a fixed charge based on the property value, and the charges are not always related to the actual volume of water used. According to the NSW State Treasury, marginal cost recovery for urban water usage ranges from about 6 per cent at low use to 22 per cent at annual use levels of 400 kilolitres. Again, consumers have little incentive to avoid excessive water use (Environmental Protection Authority NSW).

Table 4: Charges for Water Use, NSW

Type of property	Water board charges		
	Service availability charge	Usage charge ($ per kilolitre)	
		0-600 L/day	822 L/day
Residential:			
First $33,000AV	$24.55	0.21	0.59
thereafter add charge per $AV	0.044 cents		
Non-Residential:			
First $2500 AV	$24.25	0.21	0.59
thereafter add charge per $AV	1.600 cents		

AV = Assessed value of property.
L/day = litres/day.

Source: Environmental Protection Authority NSW, 1994

Chisholm identifies two instances of market failure due to cheap irrigation water: the off-site effects such as reduced water quality and siltation of waterways, and excessive use of water to flush out salt from land. Cheap irrigation water contributes to the algal bloom problem in two ways. It encourages greater water abstraction thus increasing the concentration of nutrients in water. It also increases the dissolution and export of nutrients from agricultural areas into waterways. The NSW government is moving towards a user pays system to obtain greater efficiency in the use of water (Sturgess and Wright).

Further, non-transferability of water entitlements has been identified as a factor causing water to be devoted to low value uses. Making private property rights transferable will help reduce overuse of water. Transferability of water permits was introduced in NSW in 1983 which led to the development of markets for water. Transferability was limited initially to only one year but was later changed to temporary transfers of up to five years. The tenure disincentives of short term transfers were mostly overcome in August 1989 with the introduction of permanent transfers.

6. Economic Policy Perspective in Managing Algal Blooms

It is increasingly recognised that economic instruments can play an important role in the management of algal blooms. These instruments can be flexible and responsive to changing technology and market conditions. They can be divided into two broad groups: (a) those which can assist in river flow management to prevent algal blooms and (b) those which help in managing the nutrients in waterways. Property rights, water pricing and transferable water entitlements fall into the first category and Pigouvian taxes and tradeable permits fall into the second category. The potential of these instruments is discussed below.

6.1 Property Rights or Bargaining Approaches

Coase argued that once property rights to resources are clearly specified, bargaining and trading will occur among the property owners and a Pareto optimal solution will be achieved. The central argument is that property rights affect the use and management of natural resources by creating different incentives. There is a growing concern that existing land tenure systems in Australia, are inadequate to ensure optimal use of land, soil and water resources. According to Johnson, while the Torrens system of land tenure conferred high security of tenure it lacked the flexibility to respond to changing environmental needs. For example, at present a farmer can mistreat his land without payment for lowered water quality effects elsewhere. A change which makes explicit property rights on such off-site effects would improve the social efficiency of land use. However, because of lack of information on the precise costs of such off-site effects and problems of measurement and coordination, it is difficult to find a completely satisfactory solution along these lines.

In the case of algal blooms, even if property rights are well defined for land and water, it may not lead to efficient bargaining because of the large number of polluters and victims. Under such circumstances, direct negotiations among them are too complex and the transaction costs will be high. Further, agreements between two individuals might be inconsistent with the actions of a third individual. Many economists believe that the Coasian efficiency levels are not achievable in practice.

Attenuation of property rights has been adopted in addressing other similar environmental problems in Australia. Banning of tree clearing in catchments by the Victorian Government, and zoning of land implemented by the Western Australian Government to reduce the incidence of soil salinity are two examples (Greig and Devonshire). These represent second best solutions to the salinity problem. No such solutions have been considered yet for algal blooms.

6.2 Efficient Water Pricing and Transferability of Water Entitlements

Two conditions are essential for the efficient operation of a water market. There should be well defined and enforceable property rights, and the price of water should reflect the full economic costs of water use. Changes towards more efficient pricing of water are being gradually introduced in Australia. Market exchanges promote flexibility, allowing water allocations to adapt to changing economic conditions and new social values (Wonder, Morris and Wilks).

Until recent times, however, property rights to water did not reflect water quality parameters. Changes are now being introduced to water-use pricing, where the right to use water has been defined to incorporate at least some of the costs of monitoring and protecting water quality. This is reflected in moves towards an inclusive capture of water quality costs through Total Catchment Management (Sturgess and Wright 1990). Leaving more water in streams through efficient pricing creates economic benefits that exceed the benefits from transfers and diversions for off-stream uses. Moreover, stream flows and wetlands become more highly valued as growing urban populations demand stringent water quality standards and opportunities to recreate on free-flowing waters and view wildlife (Hill; Sturgess and Wright).

Transferable water entitlements are now in operation in many parts of Australia, and their wider adoption is recommended to reduce algal blooms. Here water is allocated to an agency representing in-stream users, which can trade with off-stream users. In this way water could be made available for maintaining river flows at a level which would reduce the incidence and frequency of algal blooms. In addition to flow management, efficient water pricing and transfers reduce non-point nutrients from agricultural run-off.

6.3 Pigouvian Taxes

In the management of blue-green algae, Pigouvian taxes which can be attached directly to the phosphorus that enter waterways, or to practices that result in high phosphorus run-off (eg. fertiliser use) can be used. In the former, the farmers may shift to land uses with higher returns to leached phosphorus, and in the latter, farmers will shift to technologies with higher returns to a unit of fertiliser. The main problem in using Pigouvian taxes is the uncertainty with respect to the causation, incidence, and valuation of the damage, and the difficulty of identifying pollution sources (Wills). Monitoring of nutrients from non-point sources on a continuous basis is costly and such pollution is inherently stochastic. These features make the application of Pigouvian taxes to the algal bloom problem difficult.

Further, the Murray River and other water systems have thousands of farmers and a large number of pairwise externalities. With n individuals there will be n(n-1) pairwise interactions. Such interactions prevent the precise calculation of marginal damages and the derivation of Pigouvian taxes. Imposition of taxes may also incur opposition by farmers. Pigouvian taxes will thus not be an effective instrument to control algal blooms. Many economists in Australia believe that except for large point sources, a tax to reduce phosphorus levels will not have much scope (Murray Darling Basin Commission 1992). Pigouvian taxes have not been used in Australia for the algal bloom problem.

6.4 Tradeable Permits

Tradeable permits for phosphorus have received greater acceptance among some economists in Australia to address the algal bloom problem. Tradeable permits require less information than other methods such as taxes. Here, transferable quotas are distributed to individuals, the total amount being equal to the allowable limit of pollution (Bertram). Those whose clean-up costs are low will sell-off permits and use part of the proceeds to reduce pollution. In the US, tradeable permits for reducing phosphorus are used in the Dillon Reservoir in Colorado (Cropper and Oates). Tradeable permits have also been used in the European community, but were not as popular as in the US (Morse *et al.*).

Australia's experience in using tradeable permits for phosphorus reduction is limited to some pilot studies done in the Belubula River, and the Nepean-Hawkesbury River catchment by the NSW Department of Water Resources and Environmental Protection Authority and the Sydney Water Board (Young, Gomboso and Howes). A study of tradeable permits to reduce the phosphorus pollution in the Hawkesbury-Nepean River indicates that the potential is good (Environmental Protection Authority NSW).

An important variant of tradeable permits is point/non-point trading (Letson). It means granting point sources the option of bringing agricultural and urban non-point sources under control. Point/non-point source trading thus gives the flexibility to pursue lower-cost control options. The emphasis on the control of point sources of phosphorus in Australia may result in an increase in the share of non-point pollution and the marginal costs of further point control. The Dillon and Cherry Creek Reservoirs in Colorado are implementing point/non-point trading. The Tar Pamlico River Basin in North Carolina has recently started such trading. In the Wicimico basin in Maryland, savings of up to US$245,000 (35 per cent) have been achieved in meeting a 75 per cent reduction target (Cropper and Oates; Segerson; Malik, Letson and Crutchfield).

A useful question for Australia is whether a sewage authority can sponsor conservation farming. Wynan and Edwards found the private net returns for chemical free and conventional farming in South Eastern Australia to be very similar. If so, the monetary incentives needed by a conventional farmer to shift to chemical-free farming are not high. Also there are relatively low cost ways of reducing phosphorus pollution in farming, such as retaining buffer strips with natural vegetation along waterways, preventing stock having access to stream storage banks to avoid bank damage and direct faecal contamination, requiring small animal wastes from dairies and other intensive animal industries to be treated using wetland pollution ponds (Cullen). These can be sponsored by the point source polluters and they may be more productive at the margin. Point/non-point trading is receiving some attention in Australia but has not yet been introduced (Environmental Protection Authority NSW).

7. Policies for Reduction of Sewage Phosphorus

While Pigouvian taxes, tradeable permits and property rights can be used to control sewage phosphorus, there are two other policy areas specifically relevant to the reduction of sewage phosphorus namely, control of detergent phosphorus and technological approaches such as upgrading sewage plants to remove sewage phosphorus more efficiently. These two aspects are discussed below.

7.1 Reduction of Detergent Phosphorus

According to the BGATF, detergents contribute 30-50 per cent of the phosphorus entering treatment plants in the Hawkesbury-Nepean system (Department of Water Resources). Hence reduction of detergent phosphorus will help to reduce algal blooms. The European Community has implemented controls on detergent phosphorus. Its experience shows that the costs of removing phosphorus from waste water is not high (Morse, *et al.*). In Erie County, New York, USA , both ortho and total phosphorus in streams declined by 47-33 per cent in 1971 and by 60-67 per cent in 1972 due to phosphorus free detergents (Sweeney 1973). The Canadian regulations controlling the amount of phosphorus in detergents reduced the annual amount of detergent phosphorus by 80 per cent in 1973 (Jones).

There is controversy in Australia about the effectiveness of reducing detergent phosphorus as a solution to the algal problem. Some warn of the long-term dangers of the phosphorus substitutes in detergents such as NTA and Zeolite A, and the capital costs that may have to be invested to manufacture phosphorus free detergents[7]. A 1984 study of phosphate bans in Wis-

[7] Zeolite A is generally considered safer but its co-builder PCA (Polycarboxylic acid), is generally non-biodegradable and not enough is known about the fate of PCA and its metal complexes. Phosphorus free detergents are already available in Australia and the problem appears to be one of educating consumers about the adverse impact of phosphorus on water quality.

consin and North Carolina showed that such costs were about US$50.00 to US$70.00 per household per year, in the form of extra laundry additives and increased fabric wear etc. (Viscusi).

Recently, the NSW government has announced measures to limit the amount of phosphorus to 5 per cent of the weight of the detergent. The Albury City Council is spearheading a $280,000 public education program on phosphorus, to reduce detergent phosphorus[8]. Use of phosphorus-free detergents is probably responsive to community education. Community working groups have been successfully mobilised in Australia to control other environmental problems. The control of an eutrophication problem in the Peel Harvey Estuary in Western Australia and efforts to help reduce algae in Lake Mokoan in Victoria are examples (Young, *et al.*).

7.2 Technological Approaches

Technological approaches such as upgrading or overhauling the existing sewage treatment plants can be used for more efficient removal of phosphorus. Technological solutions are extremely expensive. The Albury city council in NSW recently decided to upgrade treatment and disposal of effluent, with an additional capital cost of more than $7m and annual costs of $1.78m. For plants serving large urban populations, technological solutions may be justified, but for smaller populations such solutions may not be cost effective. In the NSW part of the Murray Darling River alone, there are 142 sewage plants, and 131 (90 per cent) of these plants serve communities of less than 10,000 people. Alternative forms of sludge disposal, such as land disposal, is another aspect that needs to be evaluated. Technological approaches are politically visible and can be introduced with relative ease. However, given the substantial costs, careful consideration of the technological alternatives using benefit-cost analysis is desirable before they are adopted.

8. Concluding Comments

A range of economic policy instruments to facilitate a reduction of algal blooms is available. However, formulation of policy for the control of algal blooms often has to contend with serious informational constraints. In such situations, caution must be exercised in initiating policies which incur significant costs. The way ahead for Australia, based on the North American experience and the findings of the Blue Green Algae Task Force, appears to be in the direction of reducing detergent phosphorus. Community education may be effective for control of detergent phosphorus, as the costs of educational programs are comparatively low and divisible. Deregulation of the water market through efficient pricing and transferability can also help to maintain improved river flows, and also reduce non-point sources from agricultural run-off. In controlling the phosphorus input itself, a tradeable permit system is the preferred alternative. In any case, experience with tradeable permits in a few pilot locations where the algal blooms are severe should be carefully evaluated before large scale introduction of new control measures, including technological controls.

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[8] Concern has been expressed about sediment phosphorus that is already there in waterways. This may be available to algae for some time even if no new phosphorus enters waterways. Also there are situations where sediment phosphorus problems have been overcome. Lake Washington is a case in point.

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