Outlook

Light in murky waters

One of the remarkable things about Australia is that it has so few natural lakes. And, except in Tasmania and the Australian Alps, most of those that we do have are salty and not permanent. Our generally low and erratic rainfall is partly to blame, so water is very important to us. We have therefore invested heavily in creating artificial fresh-water storages —both large reservoirs and farm dams.

In spite of our dependence on these man-made lakes and ponds, we know extraordinarily little about the processes going on within them. One that has worried the community and its water authorities for some years is eutrophication.

Opinions differ on quite what this is. For the purposes of this article it's the process in which water, becoming rapidly enriched with nutrients, supports excessive plant growth. This may be both to Man's advantage and to his disadvantage, but the word 'eutrophication' usually conjures up unpleasant pictures of scummy algal blooms, deterioration of fisheries, and a general lowering of the quality of the water.

Plant nutrients may come from a number of sources—both natural and man-made. The waters of the lower Murray, for example, would probably naturally contain enough to promote the growth of plants merely as a result of their being washed out of the soils along the Murray–Darling system. This is in spite of the fact that most of the soils through which the river system passes are very poor. Many lakes also slowly accumulate nutrients as they age, but the natural process takes thousands of years.

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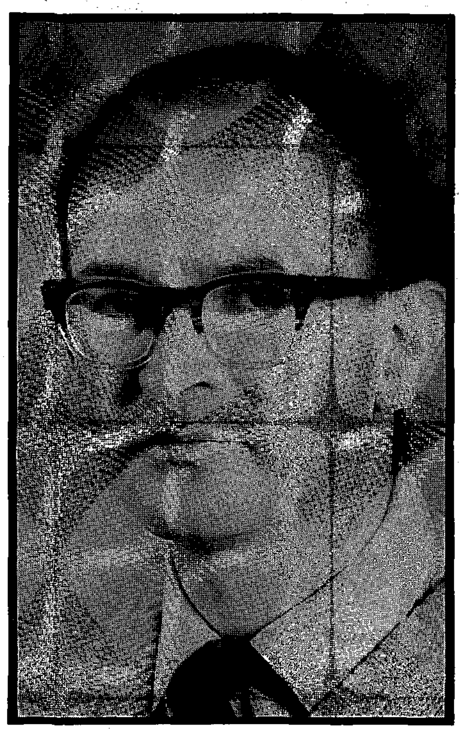

Dr John Kirk.

Nowadays nitrogen and phosphorus fertilizers used on farmland, and sewage from country towns, speed the process up greatly. Nutrients from sources such as these wash into our creeks and rivers, and hence into our lakes and reservoirs.

Eutrophication surveyed

We don't know how widespread eutrophication is in our inland waters. This was the conclusion of a national survey carried out in 1975 by Mr Gavin Wood of the then Department of Environment for the Australian Water Resources Council. We do now have some information on the nutrient levels in several of our lakes and reservoirs as a result of recent studies by scientists in government and university departments, but we have practically no older background measurements to compare them against.

In addition, it looks as though our lakes may be so different from those more extensively studied in the United States, Europe, and to a lesser extent Africa that much of that accumulated knowledge may not be applicable here.

From the human point of view, eutrophication adversely affects us in three ways:

- ▶it stimulates excessive growth of algae and other plants that make the water scummy and sometimes smelly, which detracts from the amenity value of a lake for recreation
- ▶it makes the water expensive to treat for drinking
- ▶it reduces its value for agricultural and industrial purposes

Certainly, as in other countries, Australia experiences water-quality problems in its reservoirs and farm dams. These are usually attributed to the process of eutrophication, but more often than not the case is not scientifically proved.

Ecos 3 mentioned the case of Burrinjuck Dam on the Murrumbidgee, downstream from Canberra. There's no doubt that the algal blooms that occur most summers on this reservoir are caused by nutrients coming from Canberra's effluent, and from agricultural land upstream.

Problem will remain . . .

High nutrient levels in our reservoirs create a problem that isn't likely to go away. In the case of Burrinjuck Dam, the situation will improve—since Canberra's new soon-to-be-completed sewage works will remove almost all the nitrogen and phosphorus in the city's effluent.

For reasons of cost, most reservoirs are

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located as close as possible to where their water will be needed, so their catchments are usually in demand for other purposes too. Cities like Sydney are supplied from reservoirs located fairly close by, and their catchments tend to be well populated and used for agriculture. This city's next water supply catchment—the Shoalhaven River—is heavily used for forestry and agriculture, which are both activities that may affect water quality.

To date, Melbourne has been able to close off its catchments from other uses, but it may not be able to do so indefinitely.

. . . but can be minimized

If we can't stop nutrients getting into lakes and dams, it should at least be possible to manage our artificial impoundments in such a way that the problem is minimized. But being able to do this will require much more knowledge. (Even so, some techniques for ameliorating eutrophication's unpleasant effects have been in use for quite some years.)

Nutrients are only one item that plants need for growth. Another is light. Without that no life will exist in a lake regardless of how rich its waters may be. Yet despite the importance of light, there is much we don't yet know about how it behaves in water, or how aquatic plants use it.

During the last few years, Dr John Kirk of the CSIRO Division of Plant Industry has gone some way to rectifying this. He has made both theoretical and practical studies of what happens to light after it enters Australian lakes.

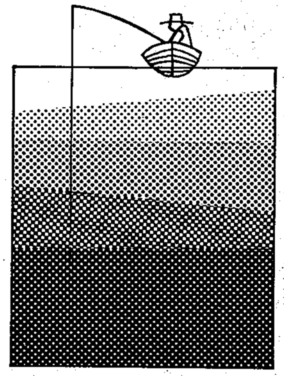
Compared with lakes studied elsewhere in the world, Australian ones seem to be particularly murky. Much of this murkiness is fine sediment and colloidal clay, but other debris and dissolved substances derived from plants also contribute.

As may be expected, the murkiness of these lakes reduces growth of algae, since the light on which these plants depend for photosynthesis cannot penetrate far into the water. Dr George Ganf of the University of Adelaide has studied a number of South Australian lakes, all of which were very murky. In theory, South Australian temperatures and light conditions should allow algal blooms to occur on these lakes during 10 months each year. What surprised him was that in practice they occur only between November and March, a period of between 5 and 6 months.

He concluded that the suspended inorganic matter making up much of the murkiness must be cutting down the light intensity so much that the growing season was becoming shortened by 4 or 5 months. So, he remarks, instead of bemoaning the turbidity of Adelaide's water, the burghers of that city should be thankful, since the murkiness helps to counteract the effects of eutrophication.

Light absorption in Australian waters

	proportion of total light quanta absorbed at 2 metres depth	
	by yellow substance (%)	by water (%)
Lake Ginninderra	81·2	18·8
Burrinjuck Dam	77·5	22·5
Lake George	75·2	24·8
Lake Burley Griffin	73·2	26·8
Cotter Dam	65·3	34·7
Clyde River (Nelligen)	63·1	36·9
Batemans Bay	29·9	70·1
Pure water	0	100



This slightly tongue-in-cheek comment points to how greater knowledge may let us manage lakes and reservoirs to keep the effects of eutrophication to a minimum.

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Dr Kirk began his studies in 1973. At that time instruments had just become available to make it possible to measure the light energy penetrating to any depth in a body of water. He was therefore able to make large numbers of accurate measurements at many depths in a number of lakes and reservoirs.

Five lakes studied

With the assistance of Mr Clive Hurlestone, also of the Division of Plant Industry, Dr Kirk studied five inland lakes of variable degrees of murkiness. These were Lake Ginninderra (a brand new ornamental lake in Canberra), Lake Burley Griffin (the city's main ornamental lake, which has now been filled for 10 years), Burrinjuck and Cotter Dams (which are both reservoirs), and Lake George (a shallow natural lake that is always very turbid). For comparison, he also sampled the Clyde River estuary on the New South Wales south coast, and the extremely clear ocean waters off nearby Batemans Bay. At the same time Dr Kirk made a theoretical analysis of what will happen to quanta of light energy in such waters, and compared the results.

Two things happen to light coming into water. It's scattered and absorbed. Scattering results from some of the light bouncing off the particles that cause the turbidity. Thus a proportion of the light can be regarded as following a zig-zag course through the water, bouncing from particle to particle.

The scattered light has to travel a much greater distance to reach a given depth than unscattered light, which travels in a straight line. Consequently the light cannot penetrate far into turbid water, since it becomes absorbed at shallow levels as it passes along its zig-zag course. In Lake Burley Griffin, for example, on average during a 2-year period 99% of the surface sunlight was absorbed in the top 1½ metres of the lake.

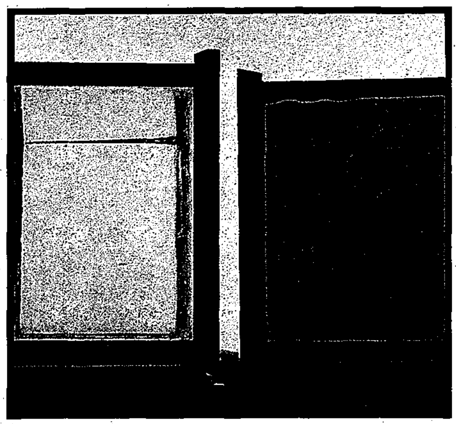
In fresh-water lakes, four separate components absorb light—water itself, suspended silt and plant debris, the chlorophyll and other pigments in algal cells, and dissolved colouring matter in the water. In inland waters, Dr Kirk has found that the last item is the most important.

Ocean water of the Tasman Sea is another matter. This usually contains next to no algae or dissolved substances that absorb light. Clean sea-water in fact has very similar light-absorbing properties to distilled water, since its dissolved salts have no effect on light.

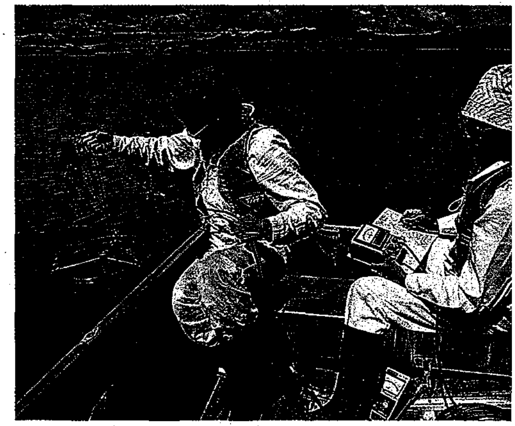
Red light absorbed

Water itself, of course, is not really a colourless liquid. It's pale blue. This means that it absorbs light from the red end of the spectrum of visible light.

Light visible to the human eye is in the waveband between 400 and 700 nanometres—400 nm being violet and 700 nm red. As it happens, the process of

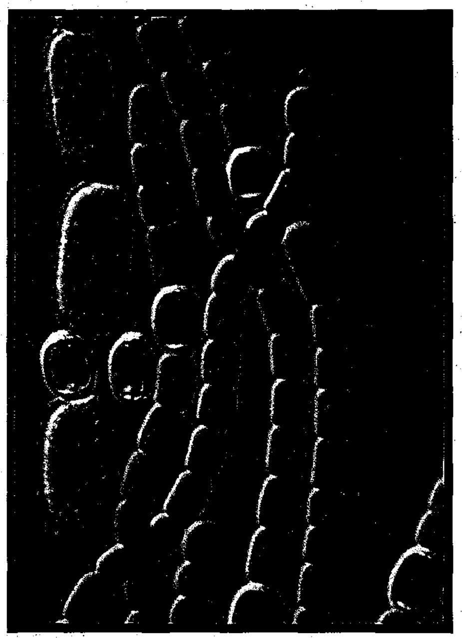


Most Australian inland waters are very yellow. Compare the colours of the water in these tanks—the one on the left contains distilled water and the other contains filtered water from Canberra's Lake Burley Griffin.



Dr Kirk and Mr Hurlestone using a quanta meter to take measurements of light penetration in Lake Burley Griffin.

Clouds reflect clearly in Lake George.



***Anabaena*—a common bloom-forming blue-green algae.**

photosynthesis uses light energy of very similar wavelengths—between 350 and 700 nm. Plants contain various photosynthetic pigments — such as chlorophyll-a, fucoxanthin and other carotenoids, and phycocyanin—which enable them to trap and use the light energy. Each of these pigments makes most effective use of a different part of the spectrum, and different types of plants contain different combinations of these pigments.

Water's blueness is unfortunate for green algae. The chlorophyll of algae makes particularly efficient use of 625- to 700-nm red light—the wavelengths absorbed by water. Five metres down in even the purest water, 90% of the red 680-nm light—the wavelength chlorophyll uses best of all—has already been filtered out. So even in very clean water containing plenty of nutrients, growth of green algae falls off rapidly as the depth increases.

In inland waters it's not only the blueness of the water itself that absorbs light. Practically always, dissolved substances derived from broken-down plant material give these waters a yellowish tinge. Coastal waters contain these dissolved substances too, although their chemical composition seems to be different there. They absorb light from ultraviolet wavelengths up to about 500 nm in the blue part of the spectrum, which explains why they colour the water yellow. Specialists know them by the unedifying German name of 'gelbstoff', or by the direct translation, 'yellow substance'. Dr Kirk is pushing the name 'gilvin', a name he has derived from the latin word *gilvus*, meaning pale yellow.

These yellow substances are not unique to Australia, in fact they were first described in Germany, which explains how they got the name 'gelbstoff'. However, Dr Kirk's studies are for the first time giving us some idea about how important they are in Australian waters.

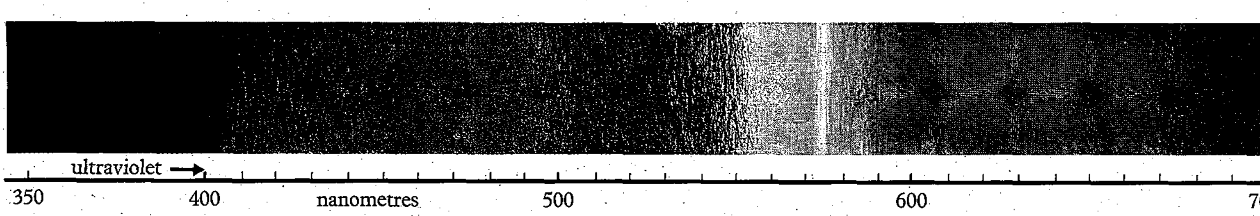
Colours reduce growth

He has found that our inland waters are particularly yellow, and this colouration is even more important than the blueness of water for reducing plant growth. In pure water, 51% of all light available for photosynthesis will reach 5 metres depth when the sun is at 45°. In filtered water from the Cotter Dam, the cleanest inland lake that Dr Kirk sampled, 6% of this light reaches that depth, while in filtered water from Lake Ginninderra, the dirtiest lake sampled, only 0·5% does so. Since all these samples were filtered, this difference has nothing to do with the lake's muddiness. The yellowness of the waters accounts for it.

In four of the five lakes that he sampled, Dr Kirk found that the yellow colouration would absorb practically all blue light with wavelengths up to 500 nm only 2 metres below the surface. Even in the Cotter Dam hardly any of this blue light reached 5 metres depth, and

Colours of the solar spectrum

The human eye sees light of wavelengths in the range of 400-700 nanometres. Green plants use the slightly larger wavelength range of 350-700 nanometres.



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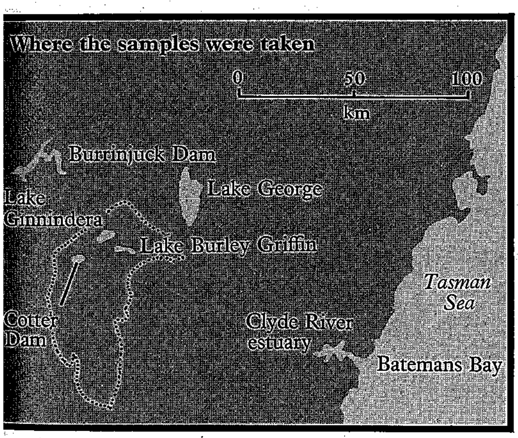
measurements made on apparently clean water from the Clyde River estuary on the New South Wales south coast gave a similar result.

This abolition of blue light not far from the surface is even more unfortunate for green algae than red light absorption by water itself. As well as making use of red light at a peak of between 625 and 700 nm, the pigments of green algae make even more use of 350- to 500-nm blue light—just those wavelengths eliminated by the yellow colouration.

In fact, Dr Kirk's studies showed, in a lake of 'average' yellowness, 70% of the light energy available at 2 metres depth ranges in wavelength between 500 and 630 nm—just where green algae can't make much use of it.



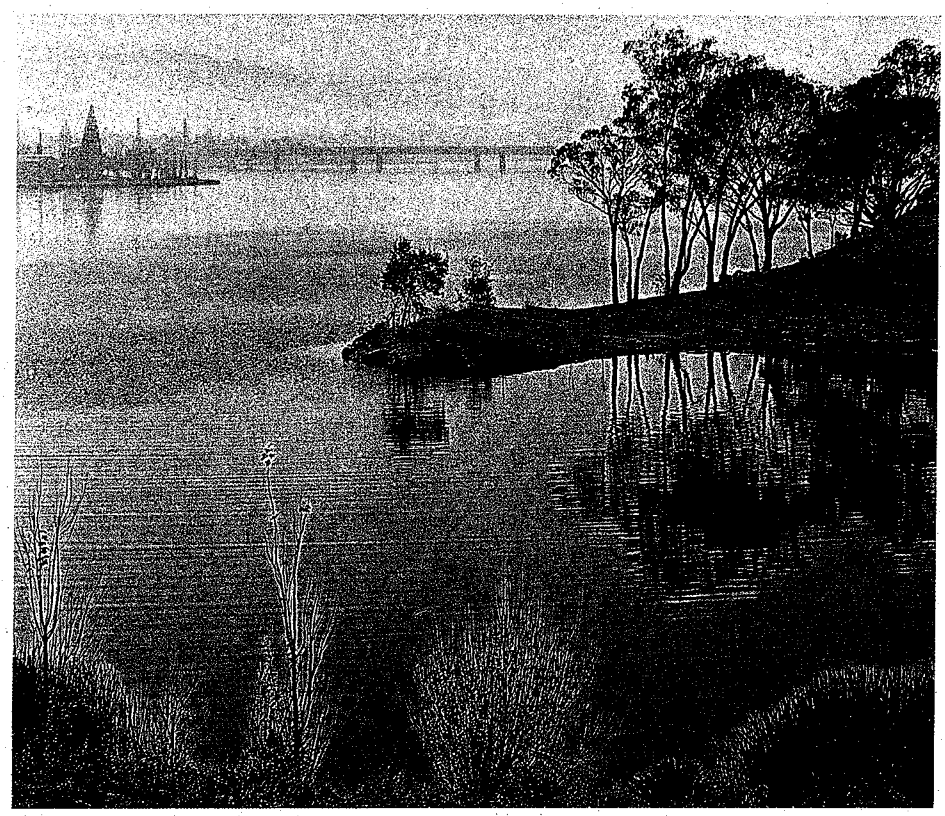
Limitation overcome

Diatoms and blue-green algae, two other types of algae commonly found in lakes, have to some extent got round this problem. Although they too contain chlorophyll and the other pigments that make efficient use of red and blue light, they also contain others able to use light energy of intermediate wavelengths. Most efficient at this are the blue-green algae, which with their phycobiliprotein pigments can use 500- to 650-nm light—the whole part of the spectrum not affected by either water's blueness or its yellowness. Brown fucoxanthin in diatoms makes use of 500- to 550-nm light.

In water containing plenty of nutrients, even these effects of blueness and yellowness can become dwarfed by surface algae in the upper layers shading out those further down. Dr Kirk has found that the size of this overshadowing for a given mass of algae depends very much on the size and shape of the plant cells in the water. When blooms occur, cells near the surface greatly inhibit growth of those further down. However, the numbers of plant cells must be such that the amount of chlorophyll-a they contain exceeds 10 mg per cubic metre of water before they have any major effect.

In summary: the picture that has emerged from Dr Kirk's work is that algae in lakes rarely grow at their full potential—even when they have warm conditions, unlimited nutrients, and bright sunlight. Absorption of light by the water itself, absorption by dissolved yellow substances, and self-shading by the algae themselves all help to inhibit cell production. Fine particles of silt and plant material that abound in the turbid conditions of most of our inland lakes also reduce the light reaching lower depths, both by absorbing some of the light directly and by scattering the light rays so that they become absorbed in the surface layers of the water.

Knowledge like this and information on how nutrients get into our lakes and reservoirs will be essential if we are ever going to learn how to manage these water bodies and their catchments so that they will continue to produce valuable water in heavily used areas.



A secluded inlet on Canberra's Lake Burley Griffin.

More about the topic

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