ARSENIC: ASSESSMENT OF AN ENVIRONMENTAL PROBLEM ASSOCIATED WITH OPERATION OF THE WAIRAKEI AND BROADLANDS POWER PLANTS

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ABSTRACT

This paper reports investigations on the fate of arsenic disposed from Wairakei and Broadlands geothermal power stations and comnents on the environmental problem.

INTRODUCTION

Ideally, there appear to be three distinct phases in the environmental management of any project.

First stage: The establishment of relevant basic factual information. The collection of information at this stage must be seen to be thorough, reliable and honest so that there be no room for doubt over the value of the information on which the environmental assessment is based.

In the Second stage: The information assembled in the first stage is used for the environmental assessment. Since this assessment is very much an exercise in prognosis it is inevitable that the degree of uncertainty in this exercise will be greater than that associated with the initial fact gathering. However, the two exercises are linked, so that smaller uncertainties over the facts are most likely to result in smaller uncertainties in prognosis. In practice these two stages are probably interwoven to some extent as initial assessments uncover the need for more data. Nevertheless it goes without saying that these two stages are completed well before the project is commenced.

Thlrd stage: As a natural outcome from the second stage an enviranmental monitoring programme should be initiated so that the initial prognosis can be checked throughout the lifetime of the project and any deviations or developments recognised and, if necessary, corrected. The responsibility for this stage should be clearly indicated.

Our involvement in the problem of arsenic discharge from the Wairakei and Broadlands fields fits into the category of third stage activities although not in the classic sense. It began more or less by chance in the 1975 when regional authorities in Auckland became concerned at the quality of water in the Waikato river which they intended to use to supplement the city's water supply. As we understood matters at that time, responsibility for the environmental management of the Wairakei and Broadlands power developments lay with DSIR.

THE ENVIRONMENTAL PROBLEM

The Wairakei and Broadlands sites are situated on the Waikato river approximately 200 km from the sea. Since its commissioning in 1961 the Wairakei power plant has discharged untreated water into the Waikato river at the rate of 6500 t hr^{-1}. The discharge rate from Broadlands is anticipated to be 2600 t hr^{-1} (Axtmann 1975). Both waters are known to contain approximately 4 µg ml^{-1} arsenic. These lead to annual discharge rates of arsenic of about 190 and 60 tonnes from Wairakei and Broadlands respectively.

The Waikato river does not flow unimpeded to the ocean. It has been heavily harnessed for the production of hydro-electric power there being eight power stations with their associated storage lakes between Wairakei and the Tasman Sea.

THE ENVIRONMENTAL ASSESSMENT

It seems that no substantial assessment of the environmental impact of the Wairakei power plant was made during planning stages. Prior to our own involvement the only original published information on the arsenic problem was that of Ritchie (1961) and Reay (1972,1973). Reay's work some ten years after the commissioning of the station appears to be the first systematic attempt to quantify the problem caused by the release of arsenic. From measurements on water he deduced that the Wairakei power plant was responsible for 75% of the arsenic in the river, and in addition he measured arsenic levels in water, lakeweed, and sediment as far North as Maraetai. He also concluded that discharge of untreated water from Broadlands would increase the arsenic input to the river by approximately 40%. He also reported problems associated with the accumulation of arsenic by various species of 1akeweed.

Our own investigations have taken place in three stages the latter two evolving naturally from the preceding ones.

In 1976 the river system was surveyed for arsenic. Arsenic levels, and, where possible, form, were measured in water, lakeweed, sediment, trout, and soil from Taupo to Tuakau the locality from which Auckland is to draw its water. Data for water and lakeweed generally confirmed and extended the information previously available, e.g. TABLE 1 compares our data, measured monthly during 1976 with measurements made by Reay at random intervals in 1971-2.

TABLE 1

Total Arsenic in Waikato River ($\mu g\ L^{-1}$)

	Reay (1973)	Aggett & Aspell (1978) range
Taupo	8	5-15
Aratiatia	28	36-95
Broadlands		31-60
Ohakuri	42	31-43
Arapuni	29	24-36
Hamilton		19-32

The arsenic appears to be present largely as arsenic(V) although on several occasions arsenic(III) was the major species. No explanation for this phenomenon has been found.

In contrast with the general agreement on water analyses and the weed problem there was a major discrepancy between our initial measurements on sediment and those reported independently by Reay and unknown NZED scientists. TABLE 2 contains a summary of the data from the three sources for Lake Ohakuri sediments.

TABLE 2

Arsenic Contents of Sediments from Lake Ohakuri

Investigator:	Arsenic Content Dry Weight Basis ($mg\ kg^{-1}$)	Number of Samples
Reay (1972)	8	1
NZED (unknown)* (1975)	3.33-5.37	4
Aggett & Aspell (1978)	201-357	5

* Reference: Coulter (1977)

Other relevant data from our 1976 survey are available in Aggett and Aspell (1978,1980).

Any doubts about the true extent of the adsorption of arsenic by sediments were settled by the results of an extensive survey carried out in 1978-9. The results obtained from the analysis of 48 cores from Lake Ohakuri are summarised in TABLE 3.

Additional samples taken from Lake Ohakuri during the third stage of activites (1980-2) suggest that the estimates in TABLE 3 are conservative. A further 33 cores

TABLE 3

Sedimentation in Lake Ohakuri

Mean depth of sedimentation since lake formation	Waikato river	26 cm
	Whirinaki arm	43 cm
Mean sedimentation rate	Waikato river	$1.5\ cm\ yr^{-1}$
	Whirinaki arm	$2.5\ cm\ yr^{-1}$
Mean arsenic content (dry weight)		$335\ \mu g\ g^{-1}$
Total accumulated arsenic since lake formation		125 t
Mean accumulation rate		$8\ t\ yr^{-1}$

from the other takes also showed elevated levels of arsenic ($80><400\ \mu g\ g^{-1}$).

However, as the number of cores available from each lake was small it is not possible to assess the problem quantitatively. Suffice to say the problem is by no means restricted to Lake Ohakuri,

Yet another potential problem became evident during these activites. In the Autumn of 1978 it was observed that the arsenic concentration in the lake water was high in samples near the sediment interface. This observation lead to a 2 year study of the mobility of arsenic in the sediments in Lake Ohakuri. It has now been shown that the Lake stratifies in Summer (January) and from this time until turnover in April-May arsenic levels build up in the hypolimnion. Mass balance exercises indicated that immediately prior to turnover in Autumn 1981 the amount of arsenic which has been released from the sediments to the hypolimnion was equivalent to 40% of the normal content of the lake. In Autumn 1982 the figure was 24%. The lower release in 1982 was in all probability a consequence of the early turnover (approximately April 12) generated by cyclone Bernie. This cyclone also thwarted our efforts to measure the pattern of the release of arsenic from the hypolimnion during turnover.

Three conclusions have emerged from these studies.

1. The immediate impact of release of untreated water from Wairakei and Broadlands would be to raise the arsenic levels in the water above the WHO recommended level for potable water possibly as far north as Hamilton in adverse circumstances. While it is possible to argue that this practice would not endanger public health unduly and that potential public users could remove arsenic in their water treatment systems, the adoption of this method of disposal cannot be encouraged because there is no guarantee that the practice would be harmless, and furthermore it would transfer the responsibility - healthwise and financewise - from the generator of the problem to another sector of the community. This is hardly a sound principle.

2. The accumulation of arsenic in the sediments is a continuing problem resulting largely from the low level of technology at Wairakei. This problem was not foreseen and nor was it recognised by those responsible for the environmental management of geothermal power in New Zealand. It is salutary to note that it remained unrecognised for sixteen years and then it was not recognised by those responsible for the environmental management of the system. It is five years since the problem was uncovered and still we play "Three Wise Monkeys". The development of technology is always likely to be accompanied by environmental problems. There is no point in ignoring them or hiding them. Professional technologists solve them. One solution is at hand (Shannon 1982).

3. The observations of the senior author throughout the project suggest that in this instance at least the environmental management practices of DSIR and NZED leave much to be desired. This is despite the fact that cooperation in the field was wonderful. At management or policy level there appeared to be no coordinated plan - or at least no adherance to one. While it must be recognised that ideas on the environment have changed radically since the mid-fifties one would have expected that by the mid-seventies professional organisations would have recognised the changing requirements and in a case such as this ensured that a continous monitoring program was initiated.

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Philippine
Geothermal Regions
geothermal area
geothermal area studied by KRTA
city
N
Cagua
Batong
-Buhay
Daklan
Acupan/
Itogon
Mainit-Bontoc
Buguias
Asin
Baguio
Balungao
LUZON
Manila
Pinatubo
Mariveles
Makiling/
Banahaw
Labo/Iriga
Mabini
Mainit-Boac
Buenavista
Montelago/
Naujan
MARINDUQUE
MINDORO
Sibuyan Sea
Isarog
Legaspi
Tiwi
Bacon/
Manito
Sorsogon
Bulusan
Biliran
MASBATE
SAMAR
Tongonan
Roxas
Naval
Burauen
Mandalagan
Tuburan
PANAY
Philippine Sea
Tacloban
Mambucal/
Saray
Sulu Sea
Iloilo
CEBU
Ormoc
Anahawan/
Cabalian
Siraan
Bacolod
LEYTE
Cebu
Palinpinon
Buloc-Buloc
BOHOL
NEGROS
Surigao/
Mainit-Placer
Baslay/Dauin
Montaneza
Santander
MINDANAO
Dumaguete
Mindanao Sea
kilometres 0 10 20 50 100 150
miles 0 10 20 50 100
Surigao/Mainit-Placer
Mindanao Sea
Philippine sea
Balatukan/Balingasag
Sulu Sea
Ozamis
MINDANAO
Malabang
Davao
Moro Gulf
Tuayan
Apo/Kidapawan
Celebes Sea
North Davao
kilometres 0 50 100 150 200
miles 0 50 100 150