THE INCIDENCE AND VARIATION OF BACTERIA IN A STOCK DAM

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Barry Hubert Pyle
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ABSTRACT

The effects of agricultural activities, including grazing and fertilizer application, and environmental factors, on the incidence and variation of bacteria in a stock dam were investigated. A survey of water quality at sites around the edge of a dam was carried out over a period of 15 months. Samples were analysed for water temperature, pH, turbidity, dissolved oxygen, 5-day biochemical oxygen demand (BOD_5), total and soluble phosphorus, total nitrogen, ammonia, nitrite, nitrate, total plate count (TPC), total coliform (TC), faecal coliform (FC) and faecal streptococcal (FS) counts.

The bacterial content of faecal samples from animals around the dam and of littoral sediments were determined. Experiments with incubation of fresh and sterilized pond water samples were carried out to examine the effects of trophic status and nitrate and phosphate addition on bacterial growth and survival.

The presence of grazing animals and wildlife around the dam resulted in significant increases in BOD_5, turbidity, FS and FC counts. Turbidity, ammonia, nitrate, $\log_{10}$TPC, $\log_{10}$TC and $\log_{10}$FC were positively correlated with the amount of rainfall in the 5 days prior to sampling. While dissolved oxygen saturation was positively correlated with water temperature, ammonia, nitrate, $\log_{10}$TPC and $\log_{10}$TC exhibited a negative correlation. Ammonia, nitrate and $\log_{10}$TPC were correlated with turbidity, and $\log_{10}$TPC was correlated positively with ammonia and nitrate concentrations. Fertilizer application resulted in slightly increased phosphate concentrations.

The bacterial content of cattle and goose faeces was similar to those reported in the literature, with FC/FS ratios less than 0.01.

FC and FS bacteria were observed to grow in sterilized pondwater samples in pure cultures and in a community of indigenous bacteria harvested from the water. Addition of phosphate and nitrate, and increasing trophic status caused growth stimulation in both pure culture and in the mixed community. In fresh samples, while indigenous bacterial populations increased, indicator bacteria survived longer in less eutrophic water.

It was concluded that BOD_5, turbidity, FC and FS counts were good indicators of animal pollution in this situation. Land drainage and mixing of dam sediments resulted in increased indigenous bacterial counts and chemical enrichment. While the physico-chemical nature and trophic status

of the water may have influenced bacterial growth and survival, direct pollution, land drainage and mixing of sediments were overriding factors. The concentrations of faecal indicator bacteria encountered suggested that pathogenic organisms such as Salmonella could be present in littoral water and bottom sediments.

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PREFACE

On farms, providing water supplies for livestock is a necessity. This creates a special problem for the extensive farming situations in New Zealand since the land is often hilly with few permanent streams. The advent of aerial topdressing in the nineteen fifties stimulated the development of large areas of such country.

This rapid development led to the increased use of stock watering dams which were built in gullies, hollows, or on slopes. In most cases stock was allowed to drink around the edge of the dam, fouling the water and breaking down the banks. On some farms the water was reticulated to troughs.

By the late 1960's it was possible to see many dams which had filled with mud to become swamps and dried up. This was due to several processes including soil erosion in runoff, increased fertility of drainage water due to topdressing, and animal contamination increasing the fertility of the dam water and mud. These resulted in luxuriant weed growth and development of a thick rich bottom mud. Where dams were shallow, particularly those excavated on slopes, the filling process was very rapid.

Along with this accelerated eutrophication process, the water which is necessary to increase the carrying capacity of the land and improve the well-being of the stock has become a source of disease for the stock. The growth of blue-green algae which produce compounds toxic to stock has become a problem. Flint (1970) included reservoirs and farm ponds in a list of eutrophic waters which would be expected to contain blue-green algae. Faecal contamination of the water has also led to potential disease transfer. Josland (1953) suggested that on farms where Salmonellosis outbreaks occur polluted water supplies were the cause.

The present study is directed at the problem of faecal contamination of the water at sites around a dam where stock drink. The thesis is that inorganic and organic pollution of stock dams by adjacent farming activities could change the nature of the water so as to encourage the survival or stimulate growth of pollution indicator organisms and/or pathogens. The incidence and variation of faecal indicator organisms was investigated over a period of 15 months, along with changes in the chemical nature of the water. Laboratory experiments were used to determine how the faecal indicator organisms reacted in waters of different trophic status.

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1. Water Pollution from Agricultural Activities:

Water pollution arising directly or indirectly from agricultural activities, both from farms or product processing plants, is either organic or inorganic. Animal wastes are basically organic in nature, containing also dissolved salts and ions (Appendix 1.1). Microorganisms which proliferate in the alimentary and urinogenital tracts abound in the wastes. Some of these microorganisms may be pathogenic to man or animals.

Agricultural activities thus affect water quality in several ways:

(i) Addition of organic waste to waterways from sheds, yards, pasture, and places where stock has access to waterways. These wastes exert an oxygen demand in the water and the products of mineralization encourage the growth of water plants and algae.

(ii) Fertilizer applications find their way into waterways directly or in runoff and subsurface drainage. Intensive farming activities increase soil fertility causing higher nutrient levels in drainage.

(iii) Agricultural practices often increase the rate of soil erosion which adds suspended material, organic matter and inorganic compounds to the drainage waters.

(iv) The numbers of microorganisms in the water are generally increased, particularly faecal organisms and possibly pathogenic organisms.

1.1 Eutrophication:

There are many interrelated processes affecting the trophic status of inland basins (Greeson, 1969), some of the more important being:

(a) the morphometry of the basin (its size, shape and volume) in relation to the size and shape of the catchment;

(b) rainfall and evapotranspiration rates in the vicinity;

(c) other climatic factors including temperature, day length and light intensity;

(d) the catchment topography and the stability and fertility of the soils;

(e) the flora and fauna present in the basin and their state of growth.

If a lake or pond was completely isolated, receiving no runoff, its nutrient status would depend upon the parent rock on which it was formed and the fertility of the rainfall. Where runoff flows into a lake or pond the trophic status will be affected by the fertility of the catchment. The agricultural use of the catchment is extremely important since richly fertilized and heavily stocked areas provide abundant supplies of soluble and organic nutrients. Erosive activity may lead to accelerated eutrophication, which is aided by evaporation. The ultimate result of this is accelerated succession or senescence of the dam which proceeds to the development of a swamp and finally a terrestrial ecosystem.

At present it is thought that only two nutrient elements need be examined with regard to eutrophication, namely phosphorus and nitrogen (Metson, 1971). Agricultural land use in New Zealand increases the concentrations of these nutrients in our waterways. (O'Connor, 1968.)

The Water and Soil Division, Ministry of Works, Nelson, (unpublished data) carried out a study on drainage from various types of catchments entering Tasman Bay during the low flow period in 1971 (Appendix 1.2). Farmed catchments yielded more nitrate, phosphorus and potassium than forested catchments. Mixed farming appeared to result in higher nitrate concentrations in runoff, while 'farming' had lower, and extensive grazing catchments still lower concentrations. The data for the Wangapeka and Collins Rivers where there were low levels of nitrate, total phosphorus and potassium, are indicative of the nutrient levels in catchments having a minimum of agricultural activity.

The chemical nature of natural waters has been extensively discussed by Hutchinson (1957) and Ruttner (1953).

1.2 Organic Pollution:

The prime sources of organic pollution on farms are the areas where stock are concentrated for prolonged periods of time or for short regular periods. On dairy farms, the main sites of stock concentration are the milking shed and wintering pads. On sheep farms, shearing sheds, yarding areas and sheep dips are the main areas. Piggeries and poultry units are also important. However, on most sheep and cattle farms, stock are concentrated in paddocks, particularly where there is water, to facilitate farming activities such as cultivation, weaning, shearing, and wintering. Rotational grazing results in temporary high stocking intensities as opposed to set-stocking.

While it is impossible to measure the exact amount of organic pollution from livestock in New Zealand or to estimate the capability of the land and water to break down the waste, it is possible to estimate the amount of waste produced and its polluting capacity. Estimates of either waste production per capita per unit time, or of comparative Biochemical Oxygen Demand (BOD) loading per capita per unit time have been made (Appendix 1.3). Population Equivalents on the basis of BOD production per human of 0.2 lb/day and by liveweight comparisons are similar in the case of poultry, pigs and cattle, but not sheep. Table I shows the total population equivalent for N.Z., in terms of its human and animal population's BOD production, using 1970-71 population estimates. The total estimate of an animal population twenty times the size of the human population in terms of BOD production may be too high, although Brown (1969) estimated a population increase of 13.9 times the human population in terms of weight of excrement.

Whatever the population equivalent is, the estimate indicates that as the areas of farmland and intensive stocking systems increase, the demand on our soils and water as waste treatment systems will be as important as the demand by urban and industrial waste treatment. At present, the most important sites of livestock concentration in terms of pollution are piggeries and poultry houses (Appendix 1.4). However, point sources of pollution such as these are easier to control and treat than non-point sources such as farm drainage.

1.3 Bacterial Contamination and Indicator Organisms:

The wide variety of heterotrophic organisms normally found in large numbers in water are extensively described elsewhere (e.g., Salle, 1967; Frobisher, 1963; Pelczar & Reid, 1965). Bacteria which are pathogenic for man and animals are normally found in small numbers, and their survival in water is limited.

The main human diseases transmitted via water are typhoid, dysentery and cholera. Diseases that could be transmitted through water containing animal wastes are salmonellosis, staphylococcal and streptococcal infections, tetanus, tuberculosis, brucellosis, and fungal and viral diseases (Decker & Steele, 1966). Leptospirosis enters water from animal secretions, especially from rats, this being a common means of transmission. Poultry manure is well-known to be a rich source of *Salmonella* organisms. It is also likely that pathogenic members of the *Escherichia* and *Proteus* genera may be transmitted through water.

Since most pathogenic organisms are usually present in relatively small numbers in water and are difficult to culture, organisms which are characteristic of faecal material and which can normally survive for longer periods in water are relied on as indicators of potential contamination of the water with pathogenic organisms. The most common of these are coliform organisms, which were thought to be characteristic of human faeces as early as 1880. The discovery of similar organisms in soils lead to uncertainty as to which were indicative of faecal contamination. Biochemical tests were then developed which could separate the coliform group organisms into strains from faecal and non-faecal sources. Later, other groups of organisms such as the faecal streptococci and some clostridia were also found to be charcateristic inhabitants of the gut of warm-blooded animals. (Geldreich, 1966, Ch.1.)

TABLE I: Equivalent Population of New Zealand in Terms of BOD Production

		Population Size[a] millions		Population Equivalent per capita	Equivalent Population millions	
Human		2.8		1.0	2.8	
Dairy Cattle -						
	Cows	2.4)	3.8	7.7[b]	18.5)	24.1
	Others	1.4)		4.0[b]	5.6)	
Beef Cattle -						
	Cows	1.5)	5.0	6.0[b]	9.0)	21.2
	Others	3.5)		3.5[b]	12.3)	
Pigs		0.5		1.7	0.9	
Sheep		59.9		0.1	6.0	
Poultry -						
	Layers	5.0		0.08	0.4	
	Broilers	10.0		0.05	0.5	
		Total Equivalent Population		=	56.0	
		Total Equivalent Population / Population Humans		=	20-fold increase	

[a]1970-71 population estimates.

[b]From Witzel *et al*, 1966, Table 5.

To determine the effect of farming activities on bacterial water quality, Thomas *et al* (1949) tested untreated farm water supplies in the U.K. Samples from shallow wells and springs and from river and canal water had the highest counts of total bacteria, coliforms and faecal coliforms. While upland surface water had relatively satisfactory coliform counts in winter when few sheep and cattle were grazing, after rain in late spring and summer, high presumptive and faecal coliform counts were observed.

Weidner *et al* (1969) found that faecal coliform and streptococcal counts in farm runoff were lower under cropping than meadow (pasture) systems. Improved meadow systems, with increased lime and fertilizer applications, contour tillage, and improved pasture species, resulted in higher bacterial runoff than the prevailing system. Stocking rates were not reported.

The M.O.W. Tasman Bay stream data (Appendix 1.2) shows that higher coliform counts can be expected in runoff from agricultural land than from forest catchments.

1.4 Conclusions:

The above data shows that as surface waters proceed from the upland catchments to the sea they are progressively polluted with inorganic and organic material. Progressive bacterial contamination also occurs. The sources of such pollution and contamination are agricultural, urban and industrial, although in N.Z. the effects of agricultural activities may continue to increase while urban and industrial sources are being controlled.

2. The Stock Dam:

A stock dam is a small expanse of water at least partially isolated from other bodies of water. In the extreme case, water enters the pond as rainfall and is lost by evaporation and seepage. In most cases, however, runoff is received from the surrounding land and during periods of prolonged runoff, water may be lost by overflow. Dams may also be situated on streams where they are continuously supplied with fresh water. The habitat is essentially one of still water (lentic), and differs from a lake mainly in that wave action is not sufficient to prevent growth of vegetation immediately at the water's edge.

The relationships between the various groups of organisms likely to be present in such a habitat were described by Lindeman (1942). The system incorporates flow of energy from primary producers through herbivores and carnivores to top carnivores, and from all these levels to decomposers, and cycling of nutrient material in a similar manner, except that decomposers return nutrients to the system for re-use. A stylized biogeochemical cycle in a pond is shown in Fig. 1.1. As well as classification by trophic levels (producers, consumers and decomposers), the organisms in fresh water ecosystems can be described by their life-form or habit and by their spatial zonation in the pond. Extensive discussion of ecological considerations can be found elsewhere (e.g., Odum, 1959; Kormondy, 1969; Brock, 1966).

FIGURE 1.1: The Biogeochemical Cycle in a Pond.
(Adapted from Redfield, 1958)