ASPECTS OF
RIVER POLLUTION

by

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FOREWORD

THERE must be very few people in this country so well qualified as Dr Klein to write a book on 'Aspects of River Pollution'. For nearly twelve years he was research chemist in the Manchester Corporation Rivers Department, where he worked on some of the many problems which arise in the treatment of sewage in a highly industrial area. He has been chief chemist with the old Lancashire Rivers Board and is now chief chemist with the Mersey River Board —an organization serving a district where an unusually wide range of aspects of pollution may be studied within a convenient distance of the laboratory. This first-hand acquaintance with polluting discharges, and with the methods which can in practice be used to purify them—bearing in mind that limitations of space, of skilled supervision, and of finance, together often determine whether a technically possible process is 'reasonably practicable' or not—is very obvious in the book which he has now written. It is being published at a time when there is much discussion on the way in which a river board can best manage the streams for which it is responsible—whether for example it should attempt to apply uniform standards of quality to all the effluents discharged in one district or whether it is better to consider each discharge separately —and on this and similar matters Dr. Klein, with his long experience, speaks with great authority.

But besides making available his own observations and thoughts on pollution, Dr Klein has rendered a tremendous service to everybody interested in this matter by surveying critically the widely scattered and now very extensive literature on the subject—he has included in his book references to more than 1,300 original papers, which means that he must have considered and rejected many times this number. Anybody who has tried to make such a search, even for the purpose of writing a review of developments during a single year or within a narrow field, will know how much labour it has involved. There are times when, surveying the great mass of papers now published and pondering on the wide differences in quality between the best and the worst of them, one fears that the system of communicating scientific information will break down of its own weight. When an expert in his field—and it requires one with unusual patience and fortitude—undertakes to bring such an unwieldy mass of material into order, and to present what is worth keeping in an assimilable form, he renders a very high service to his

fellow workers. This Dr Klein has done, and I know that the by now large number of chemists, engineers and biologists, who deal with problems of pollution and their prevention, will find this book to be of the first importance and of the greatest assistance to them in their work.

B. A. SOUTHGATE

PREFACE

It is with some diffidence that I venture to add to the already large number of books on sanitation and public health. 'Of making many books there is no end; and much study is a weariness of the flesh' writes Ecclesiastes. There is, however, a definite need at the present time for an up-to-date work dealing with river pollution in its various aspects. Since the passing of the River Boards Act, 1948, and the Rivers (Prevention of Pollution) Act, 1951, there has been widespread interest in the condition of our rivers and a demand for purer rivers by fishery interests, water undertakings and, indeed, river users in general. It was to satisfy a need for information on the problems associated with pollution that the author undertook the writing of this book.

The book is divided into 15 chapters each of which covers a particular aspect of river pollution. A short chapter has been devoted to the legal aspects of the subject as applicable to conditions in this country. I have included a chapter on the detection and measurement of pollution which is intended to supplement rather than encroach upon the ground covered by the many practical handbooks on the subject.

I am deeply indebted to Dr J. R. Erichsen Jones, Ph.D., D.Sc., lecturer in zoology, University College of Wales, Aberystwyth, for contributing a chapter on 'Fish and river pollution', and to Mr H. A. Hawkes, M.Sc., A.M.Inst.S.P., biologist to the Birmingham Tame and Rea District Drainage Board for writing a chapter on 'Biological aspects of river pollution'. The book would have been incomplete without these two important chapters. It is a pleasure, also, to express my thanks to Mr J. T. Firth, chief engineer to the Mersey River Board and his staff, particularly Mr R. A. Hargreaves and Miss L. C. James of the gauging department, for the inclusion of Chapter 11. In this chapter some physical characteristics of streams are discussed in relation to pollution. It is customary to use the minimum dry weather flow of a river as a basis for obtaining dilution factors in pollution problems. The dry weather flow, however, can vary seasonally and according to the level of the surrounding water table. We have, therefore, suggested a method of determining what we propose to call the 'standard flow' of a river. This flow (the most frequently occurring dry weather flow) is based upon a statistical evaluation of flow records over a period of at least 10 years and we consider it to be a more appropriate basis for calculating dilution factors.

Notable omissions from this book are the subjects of corrosion and the pollution of tidal waters. Corrosion is already adequately dealt with in several works. The question of the pollution of tidal waters is in a different category since much work remains to be done on this subject which some day might well form the theme of a whole volume.

It is not possible within the limits of a single book to deal exhaustively with the many aspects of river pollution. Each chapter, however, is provided with its own list of references which will enable the reader to study the subject matter in greater detail should he so desire. The total number of references exceeds 1,300 but many thousand would be required for a complete survey of the literature. In this connection, I must express my indebtedness in my search of the literature to the excellent *Water Pollution Abstracts* published monthly for the Water Pollution Research Laboratory by H.M. Stationery Office, London; and to the 20-year Index (1928–48) for the American *Sewage Works Journal* published by the former Federation of Sewage Works Associations (now the Federation of Sewage and Industrial Wastes Associations). Much of the information presented in this book is widely scattered throughout the literature and has now been collected together in one volume for the first time.

Although intended more particularly for those directly concerned with anti-pollution work, such as Government departments, river boards, local authorities, water undertakings, manufacturers, and the great nationalized undertakings, the book should also make an appeal to public analysts, consultants, sanitary inspectors, engineers, medical and public health authorities, anglers, and indeed all who value the purity of our rivers and the beauty of our countryside. Although the book is written primarily from the standpoint of British practice, much of the subject matter has application to conditions in other countries.

I am fully conscious that in many instances I have only dealt inadequately with certain topics. To do full justice to a many-sided subject like river pollution would require not one book but many volumes. Consequently, to those critics who complain of certain shortcomings in this book, I would plead, as did Samuel Johnson in the preface to his dictionary 'In this book, when it shall be found that much is omitted, let it not be forgotten that much likewise is performed'.

I am greatly indebted to Mr A. H. Jolliffe, clerk of the Mersey River Board and to many colleagues on the staff of the Board for their invaluable assistance in the preparation of this book. In particular, it gives me great pleasure to thank Mr H. Greenhouse, A.R.San.I., and Mr R. Bolton, A.M.C.T., M.R.San.I., M.Inst.S.P.

(district inspectors), Mr A. McKay, F.R.I.C. (senior assistant chemist), Mr D. Higham, B.Sc., Mr C. J. Carroll and Miss S. M. Turner, B.Sc. (assistant chemists), for reading and criticizing several of the chapters and for assistance in the preparation of some of the diagrams. I should like also to express my appreciation of the valuable critical comments made on several of the chapters by Dr T. Stones, M.Sc., F.R.I.C., manager and chemist to the Salford Corporation Sewage Works. Assistance with the photographs of some of the organisms in Chapter 8 has been given by Mr C. M. G. Keeping, A.R.I.B.A., architect, Birmingham Tame and Rea District Drainage Board, and by Mr G. F. Dixon, Member of the Birmingham Natural History and Philosophical Society, to both of whom I would express my grateful thanks. I am indebted to the divisional controller of the Central Electricity Authority for his kindness in allowing me to publish, in Chapter 5, figures relating to some generating stations in Lancashire. It is a pleasure also to thank the United States Public Health Service for permission to quote their drinking water standards; and Dr B. A. Southgate, C.B.E., director of the Water Pollution Research Laboratory, for his kindness in allowing me to reproduce a table showing the solubility of oxygen in water which is based on the most recent work carried out by that laboratory.

I am very grateful to the Editor of the American *Sewage Works Journal* (now *Sewage and Industrial Wastes*) for permission to quote material from that publication; to the Editor of the American journal *Water and Sewage Works* for his courtesy in allowing me to reproduce *Figure 2*, from a paper by Thomas, and other material from that journal; to Dr B. A. Southgate, C.B.E., for allowing me to reproduce a photograph of *Beggiatoa* (*Plate V a*) from a paper by Mr T. G. Tomlinson, M.Sc., of the Water Pollution Research Laboratory; to Mr T. G. Tomlinson, M.Sc., for permission to reproduce a hitherto unpublished photograph of *Carchesium* (*Plate V c*); and to the Controller of H.M. Stationery Office for his kindly allowing me to reproduce a photograph of *Leptomitus lacteus* (*Plate V b*); and finally to Mr W. T. Lockett, Editor of the *Journal of the Institute of Sewage Purification*, not only for his kind permission to quote material from that journal but also for allowing me to reproduce photographs of organisms (*Plates I a*, *I b*, *I c*, *II a*, *VI a*, and *VI b*) from a paper in the journal by Mr H. A. Hawkes, M.Sc., and Dr S. H. Jenkins.

Any corrections or suggestions for the improvement of this book will be welcomed by the author.

Manchester L. KLEIN

July, 1956

ABBREVIATIONS

A.P.H.A.	American Public Health Association
B.D.H.	British Drug Houses
B.O.D.	Biochemical Oxygen Demand
D.W.F.	Dry Weather Flow. This term is applied to the normal flow of a stream, or of the sewage at a sewage works, during dry weather which extends over the whole catchment or drainage area. There is no general agreement on what constitutes 'dry weather'
m.g.d.	million gallons per day
M	Molar, i.e. a solution containing the molecular weight in grammes of a substance per litre of the solution
N	Normal, i.e. a solution containing 1 gramme equivalent of substance, or amount of substance equivalent to 1·008 grammes of hydrogen, per litre of solution
p.p.m.	parts per million (i.e., grammes per million millilitres,* or milligrammes per litre)
rev/min	revolutions per minute
sp.	species (singular)
spp.	species (plural)
e	the base of natural logarithms (= 2·71828. . . .)
<	less than
>	greater than
g/l.	grammes per litre
mg/l.	milligrammes per litre
mV	millivolts
atm	atmosphere (pressure) = 14·7 lb./in.^{2}
lb./in.^{2}	pounds per square inch
h	hours
ft.^{3}/sec	cubic feet per second (cusec)
gal./day	gallons per day
ft.^{3}	cubic feet
μg	microgrammes
ml.	millilitres
gr	grains
μcurie/l.	micro-curie per litre

The abbreviations appearing in Chapter References are taken from *World List of Scientific Periodicals* (Butterworths, London).

* Definition given by Ministry of Housing and Local Government in Circular No. 8/54, 1954. In British units, it is, for all practical purposes, approximately equal to lb. per million lb. or lb. per 100,000 gal.

CONTENTS

CHAPTER 1

HISTORICAL INTRODUCTION

Thou shalt have a place also without the camp,
whither thou shalt go forth abroad:
And thou shalt have a paddle upon thy weapon;
and it shall be, when thou wilt ease thyself
abroad, thou shalt dig therewith, and shalt turn
back and cover that which cometh from thee.

Old Testament. Deut. xxiii. 12–13

Cleanliness is next to Godliness.

CHARLES DICKENS (1812–70)
Great Expectations, ch. 4

THE disposal of human wastes and other organic refuse without creating a nuisance has been a problem since time immemorial. One of the foremost of the early sanitarians, Moses, framed a very striking and comprehensive code of health regulations for the ancient Israelites and, as the quotation given above shows, the difficulty in the disposal of human waste products was surmounted by resorting to burial of the wastes in the earth. We now know that this procedure has a sound scientific basis. It involves the breaking down of organic matter by soil bacteria to harmless and indeed useful end-products. In this way, the waste products thus restored to the soil are converted to food for plant life which, in turn, becomes again the food of animal life and man. The method is a reasonably satisfactory one so long as the population is not too large and plenty of land is available. China with her vast areas of land has for centuries practised the method of returning to the soil all vegetable, animal and human wastes and has thus been able to maintain large populations without any marked falling off in soil fertility. The problem, however, becomes more complicated when mankind seeks to live in large cities. FOWLER[1] points out that in ancient days in India towns and villages were evacuated from time to time by the population and re-established elsewhere so that the impurities of many years could be broken down by natural agencies.

Long before even the days of Moses, Zoroastrianism, the religion of the ancient Persians, laid great stress on purity and the health of mind and body, and definitely forbade the discharge of organic refuse or indeed any filth into the rivers. In modern India, on the other hand, the *Manchester Guardian* (8 July 1953) has reported that a fast unto death was being carried out by a 'Holy Man' in

order to obstruct the passing of a Bill for the prevention of river pollution!

In a fascinating paper dealing with sewerage in ancient and medieval times, GRAY[2] has pointed out that several ancient empires in Assyria and Babylonia possessed sanitary systems which would put to shame those in some of our modern towns. Both the Indus civilization (about 2550 B.C.) and the Aegean civilization (about 3000–1000 B.C.) possessed quite elaborate drainage systems constructed of brick or stone. For example, on the island of Crete, A. Mosso, quoted by Gray[2], made the following remarkable statement:

> 'One day, after a heavy downpour of rain, I was interested to find that all the drains acted perfectly, and I saw water flow from sewers through which a man could walk upright. I doubt if there is any other instance of a drainage system acting after 4000 years.'

The sewers of Rome are, of course, quite famous but they were intended to be used for the removal of rain water and underground water and not as sewers. Indeed, the filth of Rome went into the Tiber, and REYNOLDS[3] goes so far as to say that the neglect of sanitation in the declining days of Rome was the cause of the general increase of malaria, the decline in the health of the people, and the depopulation of the cities.

During the Middle Ages, when habits of cleanliness were at a low ebb, the streets in the cities of Europe were foul with excrement and filth, and the stench must have been well nigh intolerable at times. Gray[2], referring to the perils of the passer-by in the streets of those days, states that Parisians freely emptied chamber-pots from their windows and only the nimble and lucky escaped being drenched! It is even recorded that Shakespeare's father had to appear before the Burgesses of Stratford on Avon and was severely reprimanded for failing to remove dung from the front of his house. Small wonder, then, that the aristocrats of the day when walking abroad often held a clove-studded orange to their nostrils in order to make the atmosphere more tolerable.

Undoubtedly many of the plagues and epidemics that raged from time to time in those days had their origin in the insanitary habits of the people. Unfortunately, epidemics resulting from primitive or non-existent sanitation were, as KEMPSTER[4] has pointed out, popularly regarded as an Act of God or the Devil. This is very different from the twentieth-century attitude and in these times, as the Archbishop of York suggested at the Royal Sanitary Institute Congress held in York in 1912, it would be regarded as akin to blasphemy to say that 'an outbreak of disease is God's will

being done, when patently it is man's duty which is being left undone'.

The introduction about 1810 of the modern water-carriage system of sewage disposal in the towns and cities of England merely transferred the filth from the streets to the rivers. The problem was intensified in Britain by the coming of the Industrial Revolution and the establishment of factories on the banks of rivers where water was freely available for power and for manufacturing processes. This meant that large quantities of liquid and solid trade wastes, as well as crude sewage, found their way to the rivers. Many of the rivers were little better than open and stinking cesspools; fish which were formerly abundant disappeared and even water supplies were in danger. Thus, by about the middle of the nineteenth century pollution of streams had become a very serious menace to public health, particularly in such densely populated areas as Lancashire, Yorkshire, the Midlands and London. For example, in London, the result of discharging untreated sewage from a large and increasing population into the River Thames soon became manifest. Dr. William Budd, quoted by Gray[2], describes very tellingly the noxious odours proceeding from this river during the years 1858–9:

> 'For the first time in the history of man, the sewage of nearly 3,000,000 people had been brought to seethe and ferment under a burning sun, in one vast open cloaca lying in their midst. The result we all know. Stench so foul, we may well believe, had never before ascended to pollute this lower air. . . . For many weeks, the atmosphere of Parliamentary Committee rooms was only rendered barely tolerable by the suspension before every window of blinds saturated with chloride of lime, and by the lavish use of this and other disinfectants. More than once, in spite of similar precautions, the Law Courts were suddenly broken up by an insupportable invasion of the noxious vapour. . . . Day after day, week after week, *The Times* teemed with letters, filled with complaint, prophetic of calamity, or suggesting remedies.'

And, indeed, calamity did arise in London in the form of two great epidemics of cholera in 1866 and 1872.

Conditions in Lancashire were at least as bad. As far back as 1721 fishing was still an important industry on the River Mersey and the River Irwell. In fact, the local fishermen of the day were violently opposed to the scheme put forward to make the rivers navigable from Liverpool to Manchester. Up to about 1780, the use of these rivers for drinking water and for the washing of clothes was still common practice. During the late eighteenth century and

early nineteenth century, however, there was a tremendous growth of industry and population. The great cotton industry of Lancashire, as well as numerous tanneries, paper mills, chemical works and gas works, produced extremely polluting wastes which were discharged directly to the rivers together with crude sewage from an ever increasing population. There is little cause for wonder, then, that by the early nineteenth century all fish life and other aquatic life, animal and vegetable, had virtually disappeared. TURING[5] has reported that, at one time, the scum in parts of the River Irwell was so thick and solid that birds walked on it without sinking. It may have been some such condition as this that inspired the following humorous lines which, according to JOHNSON[6], were found on a board room table after a meeting of the Mersey and Irwell Joint Committee about the year 1901:

'If with a stick you stir well
The poor old River Irwell,
Very sick of the amusement
You will very soon become;
For foetid bubbles rise and burst
But that is really not the worst
For little birds can hop about
Dry-footed on the scum.'

An American counterpart is reported by FULLER and MCCLINTOCK[7] who state that at one time one of the branches of the Chicago river (appropriately called 'Bubbly Creek') became covered with such a thick scum that people were able to walk upon it quite safely.

At last, the Government decided that something ought to be done to combat the steadily increasing pollution of the country's rivers and two Royal Commissions on Rivers Pollution were appointed to study and report on the problem, one in 1865 and the second in 1868[8]. The 1st report of the 1868 commission stated that 'of the many polluting liquids which now poison the rivers, there is not one which cannot be either kept out of the streams altogether, or so far purified before admission as to deprive it of its noxious character'. The 3rd report of the 1868 commission contains very convincing evidence of the shocking state of the Yorkshire River Calder in the shape of a memorandum from an angry manufacturer written not in ink but with 'river water taken this day from the point of junction between the River Calder and the town sewer'. The writer added: 'Could the odour only accompany this sheet, it would add much to the interest of this memorandum!'

The evils of river pollution so convincingly brought home by the reports of these two commissions were now beginning to awaken the public conscience and to stir governing circles into legislative

action. The result was the passing by the Disraeli Government of the Public Health Act, 1875[9], rightly regarded as one of the foremost sanitary measures of our times. This Act clearly recognized for the first time that care of public health was a national responsibility and established a system of local health administration setting down amongst other things the duties of local authorities with regard to the disposal and treatment of sewage. Sewage was to be 'free from all excrementitious or other foul or noxious matter such as would affect or deteriorate the purity and quality of the water in any stream into which it is discharged', but unfortunately the technique of sewage purification had not yet advanced sufficiently to make this Utopian Ideal practicable. The Act of 1875 was followed in the succeeding year by another famous enactment which for the first time attempted to control the pollution of rivers by sewage and industrial wastes, namely the Rivers Pollution Prevention Act, 1876[10], which applied not only to England and Wales but also, with modifications, to Scotland and Ireland. This Act formed, until as recently as 1951, the basis of all legal action connected with pollution of rivers (see Chapter 2).

Part I of the 1876 Act made it an offence to put solid matter into a stream but it was necessary to prove that either pollution or interference with flow was caused.

Part II prohibited the discharge of solid or liquid sewage matter into a river and it was no defence to argue that the river had already been polluted by sewage upstream.

Part III of the Act dealt with manufacturing and mining pollution and Section 4 prohibited the discharge of any poisonous, noxious or polluting liquid from any factory or manufacturing process. Unfortunately, there was an amending clause in Section 6 according to which the Local Government Board 'shall not give their consent to proceedings by the Sanitary Authority of any district which is the seat of any manufacturing industry unless they are satisfied, after due inquiry, that means for rendering harmless the poisonous, noxious or polluting liquids proceeding from the processes of such manufactures are reasonably practicable and available under all the circumstances of the case, and that no material injury will be inflicted by such proceedings on the interests of such industry . . .' This amendment virtually nullified the important prohibition contained in Section 4, though no doubt it was considered necessary in order to avoid the closing down of those industries which could not comply with the law.

Part IV of the Act dealt with the administration of the law. The most interesting section, anticipating in many ways the 1937 Drainage of Trade Premises Act (see Chapter 2), enabled manufacturers to discharge their trade wastes to a local authority's

sewers subject to the conditions that the wastes must not affect adversely the sewers and that the sewerage system must be large enough to take the wastes.

Although the 1876 Act was in many ways a comprehensive and clearly drafted measure, it was to some extent in advance of its time. The administration of the law was in the hands of the sanitary authorities who were nearly all themselves gross polluters so it is not difficult to see why the Act was for all practical purposes only of limited value. Moreover, it was found in practice that it was comparatively easy for a manufacturer to evade the Law especially by making use of the amending clause in Section 6 of Part III referred to previously. Parliament had no doubt good reasons for the lenience it had hitherto shown towards manufacturers. Perhaps an explanation of this attitude is to be found in a passage quoted by WILSON and CALVERT[11] from an article in the *Nineteenth Century* in 1903 by the Right Hon. C. G. Milnes Gaskell:

> 'The manufacturers were too powerful a body to be compelled to do their duty. "Parliament", I once said to Mr. Gladstone during the last year of his life, "has been very lenient to the manufacturers." "Say far too cowardly", replied Mr. Gladstone.'

The duty of enforcing the 1876 Act was originally entrusted to the sanitary authorities (Town Councils, Urban and Rural District Councils) but the Local Government Act of 1888 gave similar powers to the County Councils. Later, river authorities were set up in some of the chief industrial areas to administer the 1876 Act, e.g.

The Mersey and Irwell Joint Committee, 1891.
The Ribble Joint Committee, 1891.
The West Riding of Yorkshire Rivers Board, 1893.
The River Dee Joint Committee, 1932.

Two other boards, namely, The Thames Conservancy Board, first incorporated in 1857[12] and the Lee Conservancy Board (an ancient board re-constituted in 1868) were originally intended mainly to control navigation only but were given anti-pollution powers which in many respects were wider than those conferred by the 1876 Act. These six river authorities, who did much valuable pioneering work, were, together with some fishery boards, the only means of enforcing the law until comparatively recent times (see Chapter 2) when under the River Boards Act of 1948 river boards were set up covering all the watersheds in England and Wales.

Much progress was made in England towards the end of the nineteenth century in the biological purification of sewage on filters,

which proved to be a great improvement on the existing land treatment method. A Royal Commission on Sewage Disposal was appointed in 1898 to report on methods for the treatment and disposal of sewage and trade wastes. This historic body sat for seventeen years and carried out many important original investigations. It is impossible to praise too highly the painstaking work of this commission whose labours resulted in the publication of nine voluminous reports covering nearly 8,000 pages[13, 14].

The 1st Report (1901) was of an interim nature and dealt with land treatment of sewage and with various artificial processes for the treatment of sewage (e.g. septic tanks, contact beds, continuous filters and chemical methods).

In the 2nd Report (1902) the evidence of experts on the bacteriology of sewage was given.

The 3rd Report (1903) gave the commission's views on the treatment of trade effluents and on the relations between local authorities and manufacturers regarding the disposal of trade wastes. One of their recommendations is of particular interest today inasmuch as it anticipated the Public Health (Drainage of Trade Premises) Act of 1937:

> 'We are, therefore, of opinion that the law should be altered so as to make it the duty of the Local Authority to provide such sewers as are necessary to carry trade effluents as well as domestic sewage, and that the manufacturer should be given the right, subject to the observance of certain safeguards, to discharge trade effluents into the sewers of the Local Authority if he wishes to do so . . . the Local Authority should frame regulations which should be subject to confirmation by a Central Authority . . . these regulations could provide definite standards for the different manufacturers as regards preliminary treatment . . .'

The 4th Report (1904) considered the pollution of tidal waters with special reference to the contamination of shell fish.

The 5th Report (1908) was in effect a comprehensive treatise on methods available for the purification and disposal of sewage. The important conclusion was reached that 'it is practicable to purify the sewage of towns to any degree required, either by land treatment or by artificial filters'.

In the 6th Report (1909), the question of the disposal and purification of wastes from distilleries was considered.

The 7th Report (1911) dealt with nuisances due to excessive growth of green sea weeds in estuaries polluted by sewage.

The 8th Report (1912) with its numerous appendices is one of the most important of the series as it deals with the question of standards and tests to be applied to sewage and sewage effluents discharging