The Veterinary Investigation Service and its Role in Toxicological Investigations in the East Midlands (1956-1988)

F G CLEGG

Doctor of Veterinary Medicine and Surgery

University of Edinburgh

July 1998

DECLARATION

I declare that I composed this thesis entitled "*The Veterinary Investigation Service and its Role in Toxicological Investigations in the East Midlands* (1956-1988)".

I also declare that the references I have made to work carried out as part of a research group, have been clearly indicated as such and that I have not submitted the thesis in candidature for any other degree, diploma or professional qualification.

26/January/99

F G Clegg

THE UNIVERSITY OF EDINBURGH

ABSTRACT OF THESIS

(Regulation 3.5.13)

of Candidate Francis George **CLEGG**

ss

ee Doctor of Veterinary Medicine and Surgery Date July 1998

of Thesis The Veterinary Investigation Service and its Role in Toxicological Investigations in the East Midlands (1956-1988).

f words in the main text of Thesis 43,000

For seventy years, the Sutton Bonington Veterinary Investigation Centre provided a diagnostic and advisory service for the veterinary practices situated in the East Midlands of the United Kingdom. A submission is made that the Centre was successful in the investigation and recording of animal diseases. Its origin and the history of the state diagnostic laboratories are given.

The mixed farming of the region was often contiguous to industry as in Derbyshire, where lead mining has continued to represent a serious threat to stock owners. The geology, geomorphology and the extraction of minerals in the region are described. Lead contamination of pasture has occurred, with consequent poisoning of grazing animals, for over two hundred years.

Three investigations of such poisonings are described, and also a case of contamination of land with lead fumes. There is a description of the losses, and of the remedial measures taken, together with the public health significance of pasture contamination with lead, in the United Kingdom.

Current regulations in the control of lead poisoning outbreaks are given. The history of lead poisoning of swans by anglers' weights is described together with the successful outcome.

The Centre investigated other poisonings including local occurrences of copper toxicity in sheep, the uptake of I **125** by swans, industrial fluorosis and molybdenosis of cattle and there were trace element enquiries related to the use of land reclaimed by infilling with pulverised fuel ash. The poisoning of wildlife was also a province of the Centre. It was involved in national investigations of aflatoxicosis in cattle and guinea pigs, ergotism and "ryegrass staggers" of sheep, bovine botulism and haemolytic anaemia of ruminants due to excessive feeding of *Brassicae* sp. fodder.

The past success of veterinary diagnostic laboratories, and their future, are discussed in view of the impending changes in the control of residues in animal products. Their role as a tocsin in cases of chemical contamination is illustrated.

Acknowledgements

I wish to thank my colleagues in practice and in the Veterinary Investigation Service, for their assistance in describing the enquiries. I also wish to thank the laboratory staff of the Sutton Bonington Veterinary Investigation Centre and the Central Veterinary Laboratory for their constant support and high standards of expertise, and my wife, for correcting the proofs.

Figures 19 and 20 are reproduced with the permission of the Controller of Her Majesty's Stationery Office ©. Figures 29 and 30 are reproduced from the Ordnance Survey map with the permission of Her Majesty's Stationery Office © (ED 61A). Figure 31 is reproduced with the permission of the Royal Commission on the Historical Monuments of England, © Crown Copyright.

I wish to acknowledge the British Geological Survey for permission to reproduce the maps of lead and molybdenum distribution (Figures 14 and 15) from the Regional geochemical reconnaissance of the Derbyshire area No. 70/2, National Environment Council, and both the British Geological Survey and the Institute of Mining and Metallurgy for permission to reproduce the map of the South Pennine Orefield (Figure 8) from the publication "Metallogenic and exploration criteria for carbonate-hosted ore deposits - a multidisciplinary study in Eastern England" edited by J A Plant and D G Jones (1989).

TITLE: The Veterinary Investigation Service and its Role in Toxicological Investigations in the East Midlands

(1956-1988)

Abbreviations

ADAS Agricultural Development and Advisory Service

AGRG Applied Geochemistry and Research Group
Imperial College, London

AHD Animal Health Division of MAFF

CEGB Central Electricity Generating Board

CUEP Central Unit on Environmental Pollution of the DoE

CSFD Chemical safety of Feed Division of MAFF

CVL Central Veterinary Laboratory

DoE Department of the Environment

EEC/EU European Economic Community/European Union

EFPD Emergencies and Food Protection Division of MAFF

EMR East Midland Region of the UK

FScD Food Science Division

HMSO Her Majesty's Stationery Office

MAFF Ministry of Agriculture, Fisheries and Food.

MHS Meat Hygiene Service

MRC Medical Research Council

NCC Nature Conservancy Council

PHLS Public Health Laboratory Service

SVS State Veterinary Service

VMD Veterinary Medicines Directorate

UK United Kingdom

VIC Veterinary Investigation Centre

VIDA Veterinary Investigation Diagnosis and Analysis

VIO Veterinary Investigation Officer

VIS Veterinary Investigation Service

VLA Veterinary Laboratory Agency

I. INTRODUCTION

This thesis is a record of the investigations made into the poisoning of animals and birds in the East Midland Region (EMR) of the United Kingdom (UK) and which occurred between the years 1956 and 1988. The aims of the thesis are :-

1) to describe the work of a diagnostic veterinary laboratory in this area of mixed farming and industry.

2) to describe the agriculture and geology of the region and the effects of mineral extractions.

3) to describe the course of the investigations of cases of animal poisoning and in particular, the unperceived scale of lead toxicity affecting grazing animals in Derbyshire.

4) to demonstrate that such veterinary enquiries should be seen as part of the general environment in relation to public health.

5) to discuss the future of environmental epidemiology in view of past successes and failures.

In the East Midland Region of the United Kingdom, agriculture and industry have existed side-by-side for centuries. In the post-war years a considerable increase in the scale of problems resulted from new industries. Many parts of the UK are intensively farmed and widely industrialised but in addition, the EMR has also been extensively exploited by workings for minerals. During this time, there were considerable changes in both agriculture and industry which were reflected in the variety of intoxication which occurred and in the number of previously undescribed causes of poisoning which were found. The first and major part of the thesis describes the advances that were made in the understanding of lead poisoning of animals.

Advances in laboratory techniques allowed greater accuracy in diagnosis and investigations could be carried out expeditiously and on a large scale. In particular, new methods of sampling and recording using geochemical reconnaissance revealed the risks from heavy metals which exist for animals and man in parts of the region.

The history of the state veterinary diagnostic laboratories and of the later Veterinary Investigation Service is given. The role, the methods of investigation and the methods of reporting are described.

The agriculture of the region is described together with the post-war changes, and the juxtaposition with industry and mineral workings. The extractive industries include gravel pits, limestone quarrying, coal mining and the extraction and refining of lead. A simplified description of the geology of the EMR is followed by a more detailed account of the structure of the north Derbyshire ore field.

Of the hundred scientific publications published by members of the staff of Sutton Bonington Veterinary Investigation Centre (VIC) between 1955 and 1988, one fifth describe poisoning cases and many of these proved to be of national significance. Publication of these results was followed in some cases by changes in agricultural practice and by changes in legislation. The publications by members of the staff of the Sutton Bonington Veterinary Investigation Centre were made during a time of increasing knowledge and of heightened public awareness. The significance of tissue residues and their ultimate risk to human beings was becoming understood as was the fact that the grazing animal could become a vehicle for environmental contaminants in human food. Man with his longevity is most at risk of all animals from cumulative poisons and large safety margins have to be allowed for the intake of any such poisons. Farm animals on the other hand require different standards because of their relatively short life spans. The limit to the intake of heavy metals by animals was largely determined by the effects on the health and production of a herd or flock. Now however, the safety of the animal tissues for human consumption has become more and more limiting by the uptake of animals.

The first enquiries at the Sutton Bonington VIC were made at a time when the significance of pollution was less well-understood and when there was a less well-informed public. There was perhaps, a casual attitude to the dangers of the use of chemicals in agriculture and veterinary medicine. Great quantities of chemicals were being put into the biosphere with little consideration being given to their eventual fate in soil and water.

There are several ways in which livestock may be exposed to poisons:-
- by inclusion of toxic materials in feedstuff or natural diets,
- by overdose or misuse of a medicinal product,
- by the animals themselves finding and ingesting toxic substances,
- and rarely by the inhalation of toxic gases or fumes.

Most investigations to be described in this thesis were found to be due to the inclusion of poisons in the feedstuff or in the plant material offered to the animals. These include aflatoxicosis, poisoning due to S-methyl cysteine sulphoxide (SMCO) in *Brassicae* sp. crops, copper poisoning, fluorosis and most cases of plumbism. Lead poisoning of swans followed the voluntary uptake of lead shot. The case of bovine botulism followed the active search for offal by the cattle.

The poisoning of cage birds following the inhalation of fumes was described by Blandford et al (1975) working at Sutton Bonington. Further investigations into the poisoning of birds and humans by polytetrafluoroethylene (PTFE) fumes are described.

The results of the misuse of medicinal products were investigated on several occasions. Analysis of the results of all enquiries in the UK were reported latterly under the provisions of the Suspected Adverse Reaction Surveillance Scheme (SARSS) mounted by the Agriculture Departments of Great Britain.

Veterinary Medicines in the UK are licensed under the Medicines Act 1968 where the Licensing Authority is defined as the Health and Agricultural Ministers acting together. The Veterinary Medicines Directorate (VMD) as an executive agency of the Ministry of Agriculture, Fisheries and Food, operates the SARSS as the executive arm. An adverse reaction is one which is noxious and unintended whilst a serious adverse reaction results in deaths or severe lesions.

The SARSS was alerted by Hopper et al (1986) when they reported a case of selenium toxicity in lambs. Enquiries by these workers at Sutton Bonington VIC found inadequate mixing of a trace element supplement which had then been added to an anthelmintic drench.

This thesis describes the role of the state in a wide variety of toxicological investigations of domesticated, wild and companion animals. A statement by the Royal College of Veterinary Surgeons in the Guide to Professional Conduct 1990, recommends the course of action that should be taken when unexpected sequelae follow the use of the proprietary products of pharmaceutical companies and feed manufactures.

A case for a national monitoring service to search for evidence of environmental health disease problems, was made by Pinsent (1973). The service would have been based on the vigilance of general medical practitioners. It was envisaged that there would be a co-ordinating centre, which would use methods devised by the Royal College of Practitioners for assessment of morbidity. Changes in established morbidity patterns - or birth abnormalities - could have led, for instance, to the investigation of abnormal mineralisation and airborne hazards downwind from industrial complexes. This far-seeing concept was not adopted in the UK although general practitioners would not only have benefited from knowledge of existing local hazards but they could also have played a vital role in understanding new hazards as they were presented. Coggon (1995) summarised the findings of a working group set up by the Medical Research Council in 1993 to examine ways to improve the assessment of environmental exposures and to formulate a research strategy on environmental pollution. The group identified three main needs which are the same ones that are required for enquiries into risks to both domestic animals and to wildlife.

The Public Health Laboratory Service (PHLS) of the UK has not usually been engaged in toxicological investigations, other than those of microbiological origin such as botulism.

A public health enquiry into the poisoning of humans at Camelford, following pollution of drinking water for three days, was reported in the UK (Lowermoor incident Health Advisory Group 1989). The report was followed by considerable criticism of the conduct of the enquiry

(Baxter 1991: Mayon-White 1993). The need for the organisation of multiple agencies, both local and national, was stressed. It was suggested that general practitioners and health scheme trusts should be required, by their contracts, to participate in major incidents and the need for high quality epidemiological assessment early in such incidents was recognised. Allen and Sanson (1989) made a limited assessment of the risks to animals which may have drunk this water during the first few hours of the pollution. No significant or deleterious effects on farm livestock were envisaged from this wholly theoretical exercise.

An information bureau, the Veterinary Poisons Information Service (VPIS) commenced its work in 1992 on a fee-paying basis for veterinary surgeons and also for animal welfare organisations. This body claimed that the number of enquiries it received allowed it to provide a reliable source of information on animal toxicology and further claimed an ability to alert industry about agents causing concern and an ability to monitor changing trends in poisoning (Campbell and Hodgson 1994). Whether a commercial organisation can take on the role of gathering intelligence is open to discussion.

Nationally, a pioneering recording system named the Veterinary Investigation Diagnosis Analysis (VIDA) commenced in 1975 and this scheme continues to operate. The system depends on the computerised files of the diagnoses made from all the twenty-three VIC's of England, Wales and Scotland. Information has been used from VIDA in the compilation of various State Veterinary Service annual reports and also for retrievals requested by interested scientists (Hall et al 198O). The consistent demands for information from this data bank despite the accepted limitations of VIDA are described in this thesis. VIDA recorded that 1% of all the diagnoses made were cases of poisoning. Of these, three quarters were due to lead (Lloyd 1983).

From 1956 to 1988, the Veterinary Investigation Service (VIS) attempted to investigate all reported causes of farm livestock loss. Limitations were not placed on the Veterinary Investigation Officer (VIO), irrespective of whether the losses were due to microbiological or chemical causes.

The VIS also published the national VIDA records of the occurrence of poisoning cases in England and Wales. The seasonal and geographical distribution of specific poisoning cases are available for cattle, sheep, pigs and poultry. Thus, the distribution of lead poisoning in sheep can be demonstrated seasonally on a county basis. In addition, VIS staff of other Veterinary Investigation Centres (VIC) published extensively and thus the description of new - or serious cases - of poisoning were available to veterinary practitioners. Priority was given to making such publications in the Veterinary Record as this journal was published weekly and had an extensive circulation amongst veterinary practitioners in the UK and elsewhere world-wide.

The Medicines Act 1968 requires UK companies to record all adverse reactions to the licensing authorities (Kidd 1990). Ideally, the legislation of a country should involve the gathering of all intelligence on the poisoning of all animals, including companion animals but in the United Kingdom, this is not the case. The role of the Veterinary Medicines Directorate (VMD) is to encourage veterinary surgeons, doctors, farmers and members of the public to report any suspected adverse reaction involving veterinary medicines only.

An increasing number of reports has resulted in the setting up of a priority system according to the severity of the reaction and of an "Alert Group" of veterinary toxicologists and pharmacists.

The VMD is responsible also for the surveillance of residues of veterinary medicines in meat and animal products in the United Kingdom and produced its first Annual Report in 1996 (VMD 1996). The directorate operates two complementary programmes. The first is a statutory programme to implement European Union legislation under the obligations set by EC Directive 86/469/EEC. The second is a non-statutory surveillance of foods which includes the presence of the heavy metals, lead and cadmium, in meat. The work on the non-statutory surveillance is carried out under the auspices of the Working Party on Inorganic Contaminants in Foods. In 1995, the statutory surveillance carried out by the VMD extended to the collection of 47,000 samples from slaughterhouses, which were examined for the presence of some 82 residues. In the same year, the non-statutory surveillance extended to 3,600 samples of meat and offal products purchased at retail outlets and were subjected to some 11,700 analyses.

The limitations found in relating the raised heavy metal values to epidemiological and geographical information is accepted. However, the consistent finding of raised cadmium in horse kidneys (28 out of 29 in 1995) indicates the need for constant awareness of the risks and led to the voluntary agreement with horse slaughterhouses to discard the offal from animals destined for human consumption.

A case is made in this thesis that the functions of investigating and reporting poisoning outbreaks were carried out with some success. The thesis describes the structure of the VIS within the SVS and MAFF and the role of veterinary surgeons in practice, and the new and inexpedient changes in the organisation which have since taken place.

The discussion will consider the competence of past investigators and the changes in legislation and new responsibilities. Future toxicological investigations may be necessary into more dangerous and insidious losses. Any failure to arrive at an early diagnosis and to institute control measures will not be excused by the informed agriculturist of today - nor by the increasingly health conscious consumer.

II. THE VETERINARY INVESTIGATION SERVICE

Introduction

The Veterinary Department of the Privy Council which had been established in 1865 to counter the disastrous losses of cattle from rinderpest was to be the forerunner of the present State Veterinary Service. This was the first occasion in which there had been direct participation of the Government in the management of animal disease in the United Kingdom. The first veterinary laboratory in the UK was set up in 1893 at a cost of £300 in a basement of the offices of the Board of Agriculture at 4, Whitehall Place, London and it was to remain here for twelve years. Table 1 shows the history of the state veterinary laboratories and the years of development.

The first control measures were largely administrative. However, the Swine Fever Order (1893) required that viscera from suspected cases should be submitted to the laboratory of the Board of Agriculture in the UK and that specified organs were to be examined there for lesions. The workings of this order can be seen as the origin of the development of all the government veterinary laboratories. The Department had previously received diagnostic assistance from the Royal Veterinary College in Camden Town London.

Stockman was appointed as Chief Veterinary Officer in 1905. His great ability as a research worker and his belief in the necessity of extending the knowledge of a disease before instigating control measures, ensured a rapid expansion of laboratory work on several diseases including tuberculosis and contagious abortion.

In 1906 premises in Sudbury were opened and were used for the diagnosis of anthrax, epizootic lymphangitis and sheep scab. By 1908, a country house at Wembley, called Alperton Lodge, was adapted as a laboratory. Diagnosis of scheduled disease continued and research work commenced on abortion, scrapie, Johne`s disease and

1893	Swine Fever Order (1893) required laboratory examination of tissues and the earliest veterinary laboratory opened at 4, Whitehall Place
1906	Laboratories resited at Sudbury in north London by Stockman
1908	Laboratories resited near Wembley
1913	Stockman's evidence to Departmental committee on need for research
1914	Grant of £28,650 to purchase building and land
1917	Appointment of the first Veterinary Advisory Officer at Cardiff
1925	Appointment of J W Ironside as VIO at Sutton Bonington
1926	Death of Stockman in office and separation of duties of CVO and Director
1937	Agriculture Act (1937) transferred veterinary investigation duties to CVL Establishment of Biochemistry, Bacteriology, Parasitology, Pathology and Poultry Departments
1946	VIS incorporated into Ministry of Agriculture
1952	Establishment of Virology and Diseases of Breeding Dept at CVL
1955	Ministry of Food merged to form MAFF
1956	Biological and Standards Department - later the Veterinary Medicines Directorate
1960	Radio-isotope monitoring commenced by Biochemistry Dept CVL
1966	Department of Pathology and Epidemiology created at CVL

TABLE 1 Outline of the history of state veterinary laboratories.

other conditions including bracken poisoning. Accommodation at Alperton Lodge was inadequate and it was recognised that this was limiting the scope of the work.

In 1912, the President of the Board of Agriculture had written in support of an improved laboratory:-
" We venture to express our opinion that such an Institute is absolutely necessary to enable the Board of Agriculture to fulfil its duties to stock owners and for the amelioration of the disabilities arising from diseases of animals under which farmers suffer".

The need for a central veterinary laboratory was becoming apparent after the first world war because of the inadequate facilities and also because of the threat of the introduction of rabies. The Development Commissioners granted the sum of £28,650 for the new laboratory in 1914 and the Addlestone Institute, later the Central Veterinary Laboratory, was opened in September 1917.

The work of the Biochemistry Department commenced by establishing methods for the determination of the normal ranges of biochemical constituents of blood and tissues (Eden and Green 1939). Dr H H Green OBE was appointed to the Department in 1932 and he brought his experiences of the pioneering work with Arnold Theiler of Onderstepoort on bovine aphosphorosis in the veldt. Green developed micro and semimicro-analytical methods of analysis that were to become the standard methods used by VIS in all the future biochemical investigations. His importance was considerable as he initiated the future work of the department on toxicology and metabolic disease (Green 1947).

The appointment of Dr Allcroft from New Zealand in 1933 added to the momentum. The strictures on unplanned work and the accuracy of all procedures carried out by this leading internationally renowned biochemist were legendary. Dr Allcroft worked on a voluntary basis for four years until the archaic restrictions on the employment of married women in the Civil Service were removed. Together with Dr K L Blaxter, she carried out a series of classical experiments on lead poisoning of cattle and sheep (Allcroft and Blaxter 1950).

This work laid the foundations for later toxicological investigations and lead poisoning was soon established as a continuing cause of loss in calves and yearling cattle. The pioneering work of Blaxter established the levels of lead in tissues which were to be used as the diagnostic criteria for lead poisoning in cattle (Blaxter 1950; Blaxter and Allcroft 1950). In 1950, the Biochemistry Department found that 30% of the 370 submissions of bovine tissues were positive for lead poisoning and in 1964, 20% of 2,480 were found to be positive.

A case of fluoro-acetamide poisoning of livestock in Kent in 1954 was an early example of a poisoning which was to cause national concern. The Department carried out an expeditious investigation of the contamination of land occurring outside the site of a factory manufacturing rodenticides and made a rapid assessment of the dangers to livestock and humans.Other toxicological problems were soon to occur which required the help of the Department. Field and experimental studies commenced when the scale of damaging fluorosis in farm animals was found and a national survey soon followed (Burns and Alllcroft 1964). Later palliative and prophylactic measures were investigated on a Staffordshire farm with the assistance of Sutton Bonington and Wolverhampton VIC's (Burns and Allcroft 1964).

The history of aflatoxicosis and the internationally important work of the CVL followed groundnut poisoning of turkeys, cattle, pigs and guinea pigs. This work is described later in Chapter IV.

Radio-isotope monitoring of certain animal products by the Biochemistry Department started in 1960. This was to determine the levels of radio-activity and the identity of radio-nuclides in animal tissues and products. The joint investigation with Sutton Bonington VIC into the finding of the radio-nuclide I **125** in the river Trent is described later in Chapter V.

In 1966 an epidemiologist was appointed for the first time at the CVL to the newly created Department of Pathology and Epidemiology. A reporting system was devised based on the Standard Nomenclature for Veterinary Disease and Operations (SNDVO) used by Michigan University. This system was based on the anatomy of the *post-mortem* findings. It had proved valuable on a small scale with only a few reporting clinicians. However, consistency of coding was found to be difficult to achieve across a large number of diagnostic laboratories and reporting officers (Hall et al 1980). A modified system was introduced in 1973 named VIDA II which possessed the unique feature of employing a list of conditions commonly accepted as "diagnoses". In some cases, this described the causative organism

and in other cases, it described lesions observed in as yet an imperfectly described syndrome. Careful and regular reviews of the list of "diagnoses" ensured that each new diagnosis represented a widely recognised and defined entity. This led to the detection of new and emerging diseases with more certainty (Martin et al 1987). The recognised limitations of the VIDA II scheme and the caution that is necessary in order to extrapolate data are always given as a warning and this warning accompanies all enquiries:-

1. The specimens received represent a biased sample of field problems of animal disease.

2. Increases in the number of diagnoses of a condition may reflect a true increase in the number and type of submissions in the field, but may also be affected by such factors as increased awareness, or an improved diagnostic technique.

The surveillance reports of lead poisoning of cattle and sheep discussed in Chapter IV and those for copper toxicity in sheep in Chapter V, show a remarkable consistency of totals and seasonal occurrence over many years (MAFF 1995b).

The Role of the Veterinary Investigation Service

At the end of the last century eight universities and agricultural colleges were Already receiving government grants for the development of education and research. Between 1911 and 1914, eleven agricultural advisory centres were created with specialists in agricultural chemistry, dairy bacteriology, economics, entomology and mycology. In 1923, the first Veterinary Advisory Officer was appointed at Cardiff. After the first world war, extensive losses in poultry due to Bacillary White Diarrhoea caused by the organism *Salmonella pullorum* gave rise to national concern. Ex-servicemen who had invested their gratuities in poultry farming and who had then experienced severe losses from BWD, had received national sympathy. The highly successful voluntary control scheme became the Poultry Stock Improvement Plan and eventually the Poultry Health Scheme of 1966. The VIC`s took a large part in carrying out tube agglutination tests used for detecting adult carrier birds. The poultry industry was able to gain up-to-date information on the control of disease outbreaks from VIC`s at a time when veterinary surgeons in practice were untrained and inexperienced in poultry husbandry.

Opposition from practitioners to the work of these advisers occurred and resulted in a change of title from Veterinary Advisory Officer to that of Veterinary Investigation Officer (VIO). After discussion with the National Veterinary Medical Association, the forerunner of the present British Veterinary Association, instructions were given to limit the activities of the VIO. It was stated in the Veterinary Record of 1935 (Vol. **XV**, 481) that :-

"A VIO has, like other technical advisers attached to provincial centres, the two primary duties of giving advice and conducting local investigations, but he is in a special position in that he is a member of the veterinary profession and will come into frequent contact with members of that profession who are engaged in the treatment of domestic animals. In general, the cases in which advice should be given should be restricted to the following three classes of work, epizootic disease, outbreaks of obscure disease and disease prevention."

By 1932 there were twelve VIC's in England and Wales each with a VIO in charge and for the first time, there was liaison between the VIO's on national enquiries. Work at Sutton Bonington for example was directed towards the serious losses due to 'swayback' in the flocks of north Derbyshire.

In 1946, the VIC's attached to the different agricultural Colleges and University Departments, were subsumed as the Veterinary Investigation Service of the Ministry of Agriculture and Food.
In 1947, the Midland Agricultural College was included in the University College of Nottingham. In 1969, the University College became the Faculty of Agricultural Advisory Service of MAFF was set up in 1946. It was considered appropriate to incorporate the veterinary element of the Animal Health Division.

Fig 1 Map of England and Wales showing the sites of Veterinary Investigation Centres in 1968.

A Superintending Veterinary Investigation Officer (SVIO) was appointed to be in charge of the whole VIS in 1946 and placed under the Director of the CVL. Annual meetings of all VIO's now took place together with workers in the Departments of CVL. A period of expansion followed and the number of VIC's had increased to 24 by 1982. Further SVIO posts were created in 1955 and 1966 so that each region of MAFF eventually had an officer supervising the VIC`s in each region. Meetings of VIO`s were held three times a year and monthly reports of their work were prepared in addition to the valuable annual report.

Closure of the some of the smaller VIC's and amalgamations of others took place in the following decade and Sutton Bonington VIC resumed responsibility for Lindsey and Kesteven in Lincolnshire and all Northamptonshire (Fig 1).

The work of the present Veterinary Investigation Service may be divided into consultative, research, statutory and educational roles. Investigations into animal poisoning and the subsequent procedures resulted in work being carried out under each of these headings:-

a) *The provision of a diagnostic, advisory and consultative service.* The VIS provides local laboratory facilities to assist veterinary surgeons in practice with diagnosis and enquiry into herd and flock problems and thus constitutes a consultative service. For example, the VIS reported on the effects of weather on the health of the nation's livestock. Following the exceptional drought in 1976, a VIS publication described changes in the epidemiology of established disease conditions and the emergence of new diseases (State Veterinary Service 1982). This paper discussed the findings of Clegg and Watson (1960) on the first description of ryegrass staggers in the UK and its occurrence in the drought of 1959. It included observations of Chiejina and Clegg (1978) on the severe losses resulting from type II Ostertagiasis outbreaks in 1977. The VIS possessed knowledge of the epidemiology and the local geographical incidence of animal diseases. Each VIC would have experience of the local epidemiology of parasitic disease and of the effects of the region's weather conditions. This was applied to the predictions not only for parasitic disease but also for the forecasting of metabolic disease. Once the knowledge of the nutritive values of the local fodder which was to be fed in the next winter had been determined, advice could be given on supplementation to minimise losses from pregnancy toxaemia of ewes and from enzootic ataxia of neo-natal lambs ('swayback'). Advice on feeding crops of kale with known levels of toxicity was published in the region.

b) *Research and development.*

Apart from the laboratory services, the VIS provides help to practising veterinary surgeons by investigating field outbreaks of disease and in particular those associated with new husbandry systems and the advance of intensive methods. These investigations frequently result in a description of a hitherto unknown cause of poisoning.

Research may be initiated by VIS workers, sometimes in collaboration with colleagues of the relevant department of the Central Veterinary Laboratory (CVL). This may be of great importance in reporting of new problems and later in both advising and participating in their c ontrol.

c) *The support for statutory disease control and health schemes.*

Laboratory support is given to statutory and the government's animal health schemes including the Brucellosis (Accredited) Herds Scheme and the pig and poultry health schemes.

d) *Education.*

The VIC's promote and help with many educational schemes. Long staying visitors and students are welcomed from many lands. Most are supported by the Overseas Development Administration and many have been veterinary surgeons from India and Bangladesh.

Yet further changes in the organisation of the SVS took place when the Minister of Agriculture decided in 1995, that the VIC's should be run on an agency basis. On October 1, the Veterinary Laboratory Agency was created from a merger of the VIS and the CVL.

It was stated that "the resulting collaborative approach would bring together the elements of field investigation, diagnostic pathology and research and so prepared, could meet any challenges which might arise in the field of animal health". Performance targets for the new enlarged agency would have to be met.

The organisation of the Veterinary Laboratory Service which included
the CVL, the Lasswade laboratory in Scotland, and the VIC's of
England and Wales, was to be structured so that the service would be both supportive and complementary to the work of the Field Service of the SVS. This assistance was for the control of those diseases of farm livestock which were of economic importance, or which had public health significance. Indeed, assistance had always been provided diligently by the VIS, in spite of this and the many previous modifications to the existing organisation.

The wisdom of charging for laboratory examinations at a time when the livestock owner is experiencing financial loss, was questioned. Field (1972) considered that any check in the free investigation of poisoning cases could result in delays, whilst meat and milk products were on the way to being consumed by humans and that such hindrances in the investigation of poisonings could have national consequences.

The Veterinary Investigation Service in the East Midland Region

In 1892, the University College of Nottingham created the Department of Agriculture. Three years later, the Midland Dairy Institute was set up independently to provide instruction in modern dairy methods for the daughters of the farmers in the East Midlands. Table 2 shows the dates of the principal events leading to the opening of the Sutton Bonington Veterinary Investigation Centre, the other VIC`s that were created to serve all the counties of England and Wales.

In 19OO, the Department of Agriculture and the Midland Dairy Institute were joined to form the Midland Agricultural College and this was sited at Sutton Bonington, an agricultural village some 15 km from Nottingham. T W Cave MRCVS was appointed as Advisory Officer and in the same year, A Levi FRCVS was appointed as a Lecturer. Both workers conducted anthelminthic trials in sheep using copper sulphate drenches. The appointed officer was given a "job description" and was apprised that the holder "...must clearly understand that the Advisory Officer cannot undertake work which should be done by the local veterinary surgeon. He will however, be prepared to follow up the work of the local practitioner when the latter meets with obscure problems which require investigation and for which he himself has neither the time or means to conduct".

1893	University College of Nottingham creates the Department of Agriculture.
1895	Midland Dairy Institute opens at Kingston - a hamlet near Sutton Bonington
1900	Agricultural Department and Dairy Institute combine to form the Midland Agricultural College (MAC). T W Cave, MRCVS and A Levi, FRCVS appointed to posts at the MAC
1911-1914	Agricultural Advisory Offices set up in eight regions of England and Wales.
1922	Appointment of the first Veterinary Advisory Officer at Cardiff
1923-1924	VIO`s appointed at Newcastle and Bangor
1925	J W Ironside appointed as the first VIO at Sutton Bonington – dies in post 1947
1927-1964	VIO`s appointed at Liverpool (1927), Harper Adams – Tettenhall (1929), Wye (1929), Bristol (1931), Starcross (1931), Reading (1932) and Cambridge (1932), Leeds (1940), Aberystwyth (1943), Weybridge (1950), Penrith (1953), Worcester (1956), Norwich(1958), Thirsk (1960) and Truro (1964).
1965	Completion of organisation with appointment of Superintending VIO`s to the regions
1968	Enlargement of eight regional centres – Sutton Bonington in the EMR, Cambridge, Reading, Bristol, Newcastle, Leeds, Tettenhall and Aberystwyth.
1988	Closure and relocations of VIC`s reducing number to 13 plus one "VI" unit at Truro. Rebuilding and expansion of Sutton Bonington VIC to carry out national duties
1995	Creation of Veterinary Laboratory Agency

J W Ironside Veterinary Investigation Officer **(1925 - 1947)**
Dr J C Buxton Veterinary Investigation Officer **(1947 - 1966)**
F G Clegg VIO at Sutton Bonington **(1966 - 1988)**

TABLE 2 The opening dates of the Veterinary Investigation Centres of England and Wales.

In 1925, J W Ironside MRCVS was appointed as the Lecturer in Veterinary Science and the Department of Veterinary Science was created. In 1927, the laboratory moved into a Victorian house called "The Elms". The office remains within the house and extensive additions have been made to this building (Fig 2 and Fig 4).

Further extensions occurred in 1968 to enable the centre to carry out regional duties (Fig 3). A considerably enlarged and extended laboratory was built in 1989 (Fig 4) following the reorganisation of the VIC`s in England and Wales and closure of two neighbouring laboratories Lincoln and Moulton, Northamptonshire.

Ironside was well known as a toxicologist and gave his expert opinion in forensic cases throughout the UK and was also for some time the editor of Banham's "*Veterinary Posology and other Information for the use of Students and Practitioners* " (Ironside 1943). This handbook was written by G A Banham MRCVS (1853-1941) of Cambridge and was first published in 1887. The 7th edition edited by Ironside listed "Poisons and Antidotes". Only forty-seven poisons are listed and these include snake bites and alcohol. It is also stated that the incubation period of foot-and-mouth disease was from 12 hours to 12 days. Of the poisons listed, twenty-eight were either plants or products of plant origin. A separate list of thirty one "Plants which act on Butter and Milk" recalls the days of milk-maids and three-legged stools. Pepper Saxifrage (*Silaus pratensis*) now classified as *Silaum silaus* - is listed as one of the causes of frothy cream. Later editions were still referred to in the 1950's, and plant poisoning remained an important section in the 1956 edition. The considerable advances in pharmacology and the use of chemicals on the farm were not described but the Penicillin Act (1947) was mentioned and sulphonamide was listed as a possible poison. Treatment with sodium bicarbonate was recommended. There

FIGURE 2 View of the *Elms*, the oldest building of the Veterinary Investigation Service. The Victorian house was built in 1858 and the ground floor first used as a veterinary laboratory in 1935.

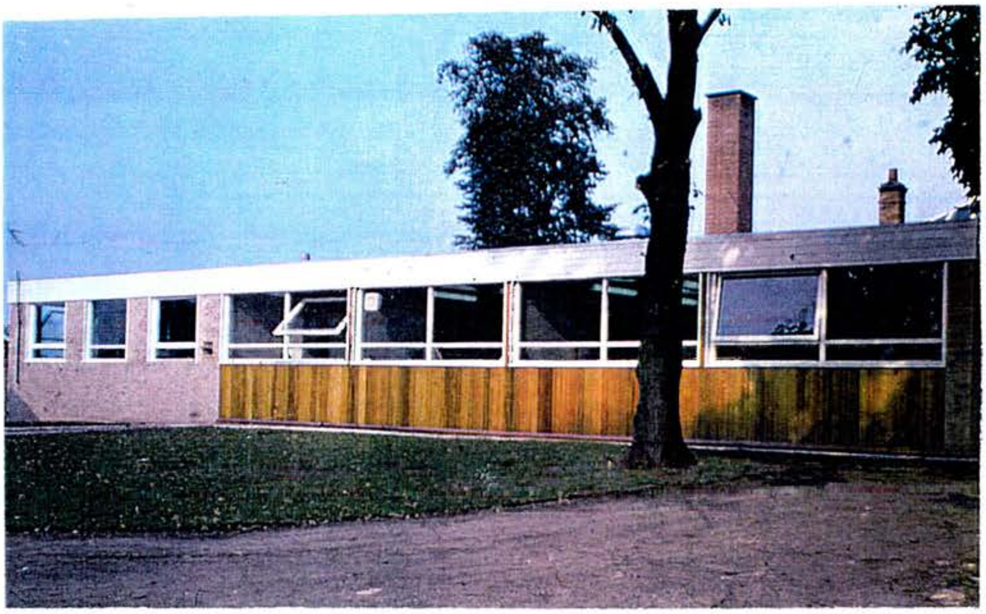

FIGURE 3 View of the 1968 extensions for regional work including general, biochemistry, bacteriology and virology laboratories.

FIGURE 4 View of the present day Veterinary Investigation Centre at Sutton Bonington. The *post-mortem* room is to the ight and the incinerator lies behind.

were no descriptions of the organo-chlorine insecticides nor of the new herbicides.

In 1937, a public lecture on sheep disease was given to a group of local sheep farmers in north Derbyshire. The meeting took place in the village of Bradwell and the sole topic of interest was the severity of the losses in new-born lambs from the condition known locally as 'warfa' - or 'swayback' (Wells 1937; Dunlop et al 1939). Dunlop learned that practically every farm in the area suffered losses of 50% to 80% and some land was becoming derelict because of this (Dunlop and Wells 1938). Owners were sending the in-lamb ewe flocks to overwinter in either Cheshire or Yorkshire as this practice had been found to prevent the condition. Dunlop and Wells estimated that 100 farms situated in an area of 38 square miles (100 square km) were experiencing losses (Dunlop and Wells 1938). At the conclusion of the lecture, the farmers formed an association to raise funds to pay for local trials on swayback prevention. This money was used was to pay for laboratory accommodation and the purchase of breeding ewes. The meeting was held in January and arrangements for the trial were complete by March. Dunlop later acknowledged that this eminently successful trial would never have taken place without the intervention of the local farmers.

Sutton Bonington VIC was to investigate one of the earliest cases of environmental contamination of agricultural land to be described in the UK. Buxton and Allcroft (1955) described industrial molybdenosis affecting cattle near a factory in north Derbyshire and demonstrated the value of continuous copper medication in feed to alleviate the condition. The new Medical School of Nottingham University opened in 1970 and the VIC collaborated in certain public health investigations.

Collaboration with Professor Webb and members of the Applied Geochemistry Group commenced in 1966 and initially trials were designed to extend the application of the geochemical reconnaissance method to the agriculture of the EMR. The Wolfson Geochemical Atlas of England and Wales was published in 1978 (Webb et al 1978) and described the findings related to regional animal health problems. Webb, Thornton and Fletcher (1968) using stream sedimentation reconnaissance methods employed to produce the atlas, reported the finding of anomalous patterns of molybdenum corresponding to the distribution of certain black marine shales in Derbyshire. The incidence of hypocupraemia in cattle in the EMR was reported by Clegg et al (1983). They found that in comparison with other counties, the incidence of hypocupraemia was greater in Derbyshire and this was especially so in the case of young stock left to graze until late in the season. These animals ingested relatively more soil containing molybdenum than the adults.

The Regional Geochemical Reconnaissance of the Derbyshire Area (Nichol et al 1970) carried out by the Applied Geochemistry Research Group, indicated the extensive contamination by heavy metals resulting from past mining and smelting activities. The results showed the usefulness of stream sedimentation reconnaissance as a means of detecting larger areas of contamination and certain anomalies were later delineated on a greater scale, together with other areas known to be hazardous to stock (Clegg and Rylands 1966).

In 1976, Sutton Bonington VIC initiated the collaboration and methods of enquiry used by MAFF in the investigation of poisonings due to pesticides and other poisons (MAFF 1995b).

The VIC was responsible for the initial reporting of the severe mortality of swans (*Cygnus olor*) on the river Trent due to lead poisoning (Simpson et al 1979) and the co-ordination of sampling for the national enquiry into the scale of loss which followed. The report of the Nature Conservancy Council (NCC 1981) described the findings and the source of the metal. Legislation was enacted to limit the use of lead in certain weights used in freshwater fishing. The VIC monitored the incidence of lead poisoning in swans for several more years.

The VIS reported on the effects of weather on the health of the nation's livestock. Following the exceptional drought in 1976, a join publication by members of the VIS described the changes the epidemiology and the emergence of new diseases (State Veterinary Service 1982).

Sutton Bonington was a typical VIC and was staffed by professional and supporting technical officers. The VIO was supported by one or more professional colleagues and by a seniortechnician, who was often an Associate or Fellow of the Institute of Medical Technology. An attached animal house held laboratory animals for biological examination of samples, for evidence of tuberculosis and brucellosis. Limited toxicological trials were also carried out. There were usually four laboratories and a "post-mortem" room equipped with an incinerator and hoist for lifting carcasses.

Fig 5 shows the principal laboratory in 1956 and Fig 6 shows a graphite furnace absorptiometer in the biochemistry laboratory of thirty years later.

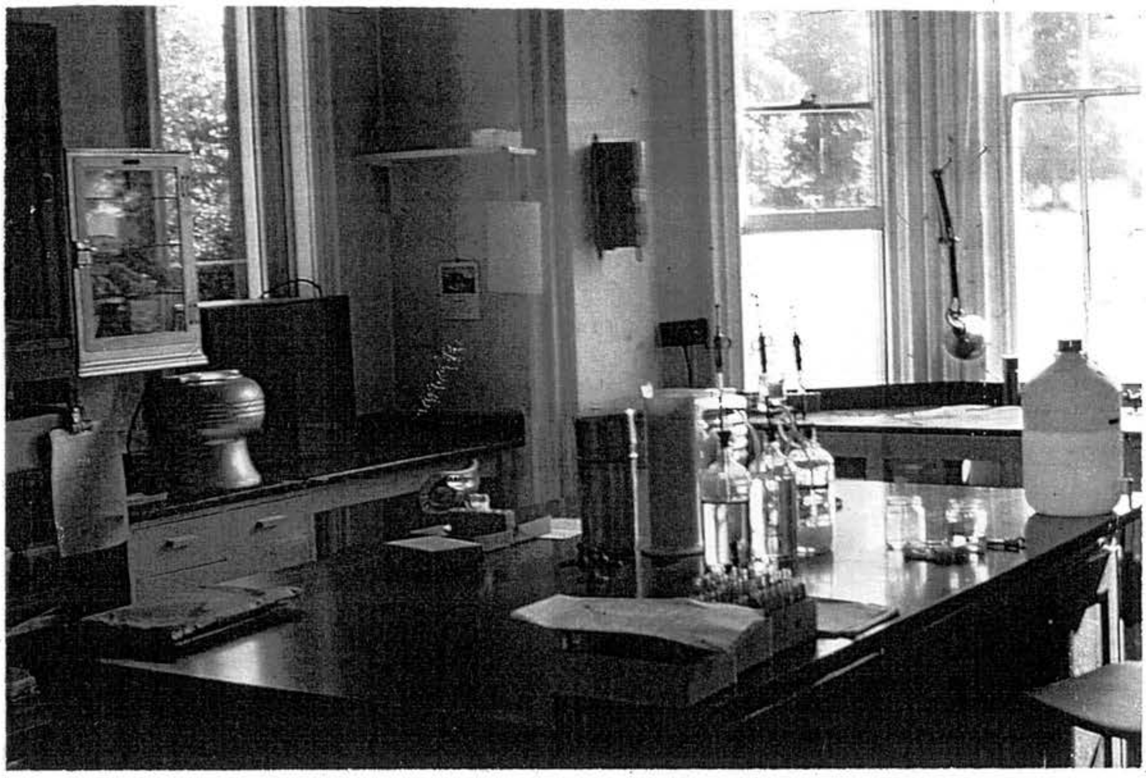

FIGURE 5 The principal laboratory in the *Elms* in 1956

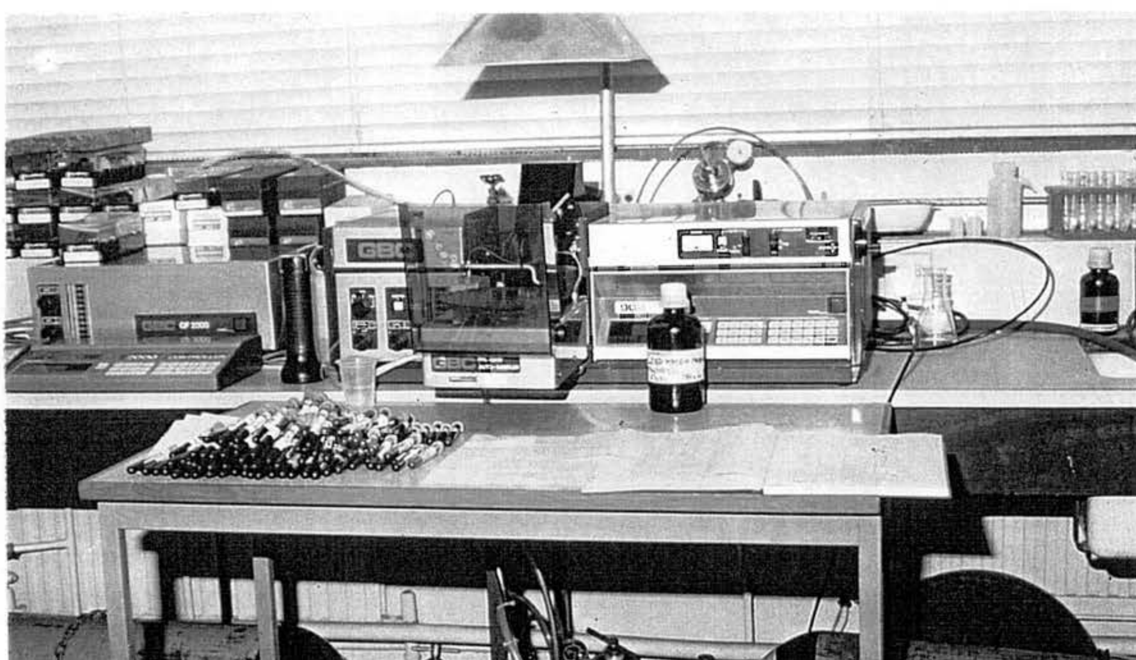

FIGURE 6 Lead analysis using a graphite furnace atomic absorptiometer (GBC 902) in 1986.

III. EAST MIDLANDS REGION OF THE UNITED KINGDOM

The Agriculture of the Region

The East Midland Region of the United Kingdom embraces the administrative counties of Derbyshire, Leicestershire, Nottinghamshire, Northamptonshire and Lincolnshire. This includes 1.26 million hectares of agricultural land and in 1976 there were 21,000 holdings.

The total livestock figures of animals kept in the region in 1975 and 1988 were (1988 figures in brackets) :-

Cattle 900,000 (810,000) including 190,000 (158,000) dairy cows and 75,000 (48,000) beef cows

Sheep 1,300,000 (1,670,000)including 560,000 (400,000) breeding ewes

Pigs 500,000 (652,000) including 68,000 (65,000) breeding sows and gilts

Poultry 13,470,000 (13,250,000)

Sutton Bonington Veterinary Investigation Centre served the first three counties from 1956 to 1988. For several periods, the Centre was also responsible for work in the other two counties.

-The agriculture of the region is one of contrasts, including the wild, bleak, peat moor land sheep farms in Derbyshire where land rises to well over 600 m, the fertile soils arising from chalk and limestone, the rich fenlands in Lincolnshire, the flat light arable sand lands in Nottinghamshire and the heavier land and the renowned store fattening grasslands of the Welland in Leicestershire. Some 90% of Derbyshire is above 60 m in elevation while in

Nottinghamshire, 70% of land lies below this height. A common feature in each county was the proximity of farming to large urban areas. Urban blight and the reckless disposal of dangerous waste were a constant cause for concern. The propinquity of the new industrial processes to farmland was a common finding during the investigation of poisonings especially in Leicestershire.

Coal mining had been of importance in Nottinghamshire, Leicestershire and Derbyshire from ancient times and remained so through the years described in this thesis. Open-cast mining was to become increasingly common. In Derbyshire, 1,000 farmers and 9,600 hectares of land were affected to a greater or lesser degree between 1942, when this practice commenced, and 1972. The excavations have not been associated with any known effects on animal health or productivity.

Mellanby (1973) reported on the evidence which had been collected by the Commission on Mining in the Environment concerning the effects of quarrying in the Peak District of Derbyshire. Mellanby attributed cattle ill health and infertility to the effects of limestone quarrying and the contamination of pastures by limestone dust. These observations were not supported by any investigation carried out by workers at Sutton Bonington VIC and the origins of the hearsay were not be found. Infertility problems associated with mineral nutrition were common in farms situated on the limestone plateau but these were found to be related to other existing conditions, and not to the operations of local quarries (Ford 1972).

Derbyshire has a long-standing history of milk production from its small farms. Farey (1817) refers to the great quantities of cheese and butter which were exported to London. When the railways were built, the opportunity was seized to supply milk to the dairies of

Lancashire and south Yorkshire. Nevertheless, the county possessed the worst difficulties for the dairy farmer - high rainfall, small holdings, small fields, unsuitable buildings and remoteness from good roads. Parts of the extreme north-west of the county have a rainfall of 1500 mm per annum and there are 25-40 days of snow cover. The high rainfall can be an important asset and grassland farming made the most remarkable advances after the war. Considerable skill was shown in carrying out direct reseeding, in the correct use of fertilisers and above all in the use of strip grazing methods. The liberal use of nitrogenous fertiliser allowed late grazing, more winter fodder and lower feed costs. Grass conservation was to replace the uncertainties of hay making. Silage making became universal and often silage pits were made by digging into the hill sides. Meandering field tracks were replaced by roads built with local limestone and later widened for bulk milk tankers and machinery.

The Peak National Park was the first of ten national parks to have been designated in 1950 under the provisions of the National Parks and Access to the Countryside Act (1947). The more precise conditions of the Countryside Act (1968) applied later. The Park covers only 542 square miles (1400 ha) but excludes industrial towns and most of the area is farmed. Most of the northern part of the ore field lies within the Park. The term Peak District is applied imprecisely to the upland area of Derbyshire as a whole. In 1968, the northern part of the Park was declared an Environmentally Sensitive Area (ESA) and the importance is that it will prevent the ploughing of lead contaminated fields.

Leicestershire experienced one of the most sudden and completchange of any county during the second world war as this predominantly pastoral county was put under the plough. However, a small area of the old ley farming continues to the present day. The county is famous for the quality of its pastures and the methods of its renowned farmer, Robert Bakewell of Dishley Grange (1725-1795) to improve Longhorn cattle and Leicester sheep, were to provide cheap meat for the growing town populations.

Nottinghamshire has a tradition of predominantly arable farming. Central Nottinghamshire is an area of forest, heath and light sandstone soils. The south of the county shared the fame of Stilton cheese production with Leicestershire. The Trent flows through Nottingham and the county of Nottinghamshire from the boundary with Derbyshire and then northwards to the Humber estuary. Six electricity power generating stations are found along its banks and these were dependant on coal from the Derbyshire/Nottinghamshire coalfield. The middle Trent valley is a valuable national source of gravel and most of the extractions are to be found along the river and its confluences. The lagoons created by the extractions were used for the disposal of pulverised fuel ash (PFA) from the generating stations. Reclamation of these sites for agricultural use has continued.

Many farms in Nottinghamshire have suffered from being on the urban fringe. The urban belt along the Derbyshire/Nottinghamshire border represents approximately a quarter of the total area of the two counties and contains over three-quarters of the population. Despite the industrialisation, the area contains 20% of the agricultural land. In this area, fluorosis of cattle was recognised as being due to the industrial use of low grade coal. Nottinghamshire was also affected by the EC Nitrate Directive and in 1990, four of the ten national plots were designated in this county. Farmers within these plots have limitations placed on their use of nitrate fertilisers.

The Geology of the Region and the Gaining of Economic Minerals

A. *GEOMORPHOLOGY*

A wide variety of landscapes is to be found in the EMR. The extensive coal measures of Derbyshire and west Leicestershire shows as low scarps where the harder sandstones stand out from the shales of the valleys in this shallow part of the coalfield. The Permian Magnesian Limestone to the east shows as a narrow plateau some 8km wide running north to south on the Derbyshire Nottinghamshire border with an escarpment 150-180 metres in height. Eastwards again is a strip of Bunter Sandstone 8-12 km wide forming Sherwood Forest and its heaths. These sandstones comprise some 80,000 acres of agricultural land in the county. The more fertile soils of the Keuper Marl form the gentle slopes in the east and to the south of Nottinghamshire and Derbyshire. Within the marl lies the Vale of Trent and its alluvium terraces (HMSO 1979).

To the north of the EMR, lie the Millstone Grit series of the Kinder Scout plateau rising to 636 m height and its steep-sided dales and open moorland overlaid with deposits of up to 3.5 m depth of peat. To the south of the EMR, the clays of the Boulder and Lower Lias form variable but heavy soils which contribute to the wealth of the Leicestershire grazings.

The Carboniferous Limestone forms the south Pennine "dome", which is a complex of folds showing a general east-west trend and which rises to a north-south line of culmination. This occurs at the point of coincidence of the two anticlines - or folds - of the arch. The Carboniferous Limestone outcrop is 40 km (25 miles) in extent from north to south and from 11 to 24 km (7 - 15 miles) wide. Fig 7 is a simplified map of the geology of Derbyshire limestone outcrop and

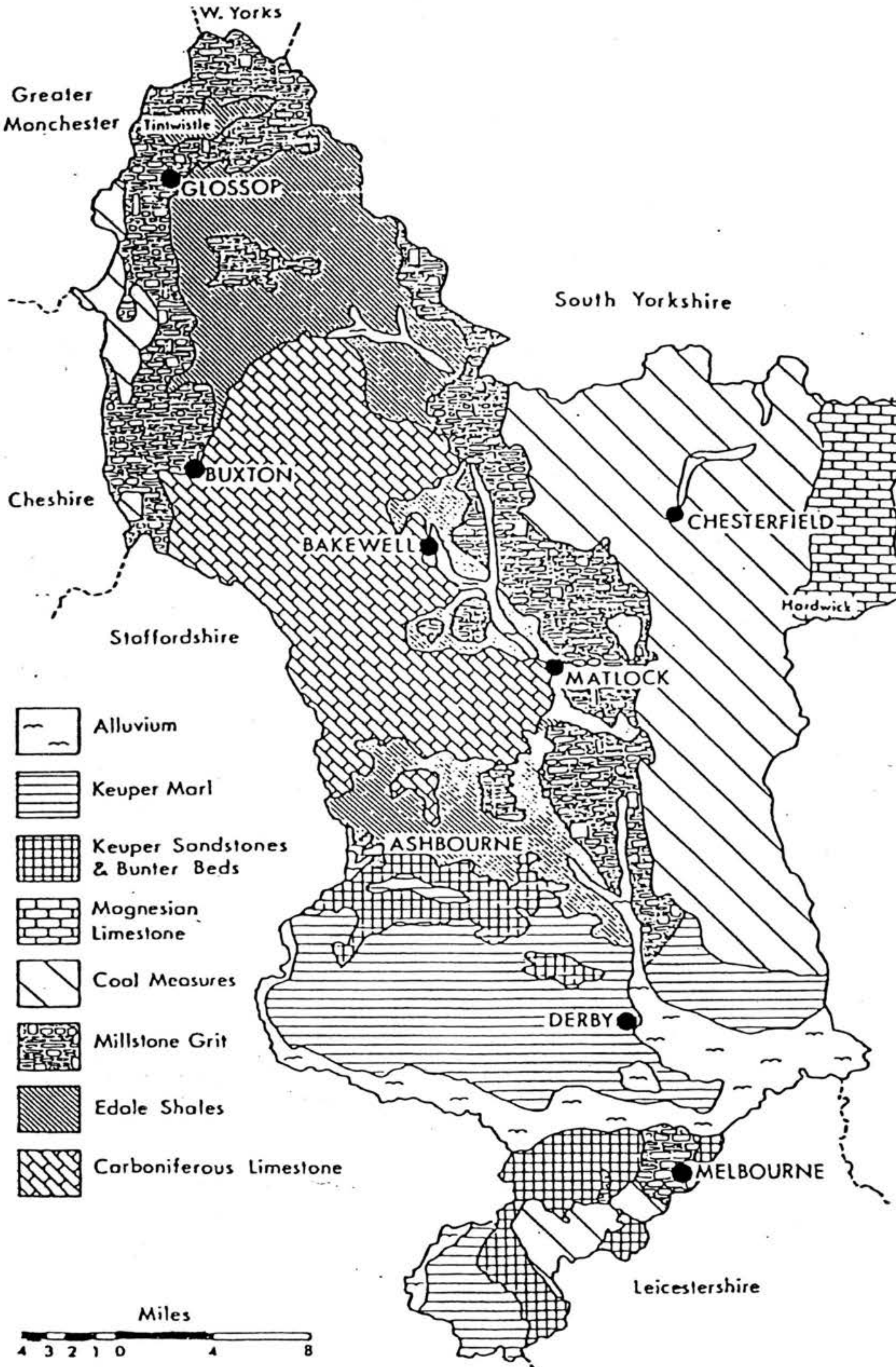

Fig 7 Simplified map of the geology of Derbyshire.

shows the position of the neighbouring towns. The thin soils of the limestone are very free-draining brown loams and the landscape is heavily fissured in places in this wide rolling open country.

B. *THE ORE FIELD AND THE GANGUE MINERALS*

Lead ore occurs in veins, sometimes in irregular masses, in the faults or joints of the limestone. It is usually accompanied by the three waste - or gangue minerals which are fluorspar (fluorite or CaF_2), barytes ('heavy spar' or $BaSO_4$) and calcite ('spar' or $CaCO_3$). Gangue is that part of the ore from which metal is not extracted. The veins fill fissures in the limestone and these rakes or linear outcrops run across country for 1.5 to 12 km and fill the vertical fractures. Some extend to 8 km in length and are a major feature of the landscape. The fissure may be 6 m

in width and occasionally more. Many have been mined to depths of 150 m. Below this, water requires drainage or pumping. Shafts were sunk along the length and the accompanying hillocks of waste still show their position. Fig 8 shows the position of the principal rakes in the orefield and of the neighbouring towns. The map shows the principally east-west disposition of the major rakes.

Scrins are minor fissures branching out from rakes which are about 0.3 m in width and extend across country for some 400 m. Flats are deposits which are parallel to the surface. Both the length and breadth of a flat is about 800 m with a depth of 6 m. The sites of shafts working a flat were close together and were found to be the to be the cause of some of the most extensively contaminated ground found in these enquiries. The richest ores, often associated with small quantities of zinc, are found in the eastern part of the

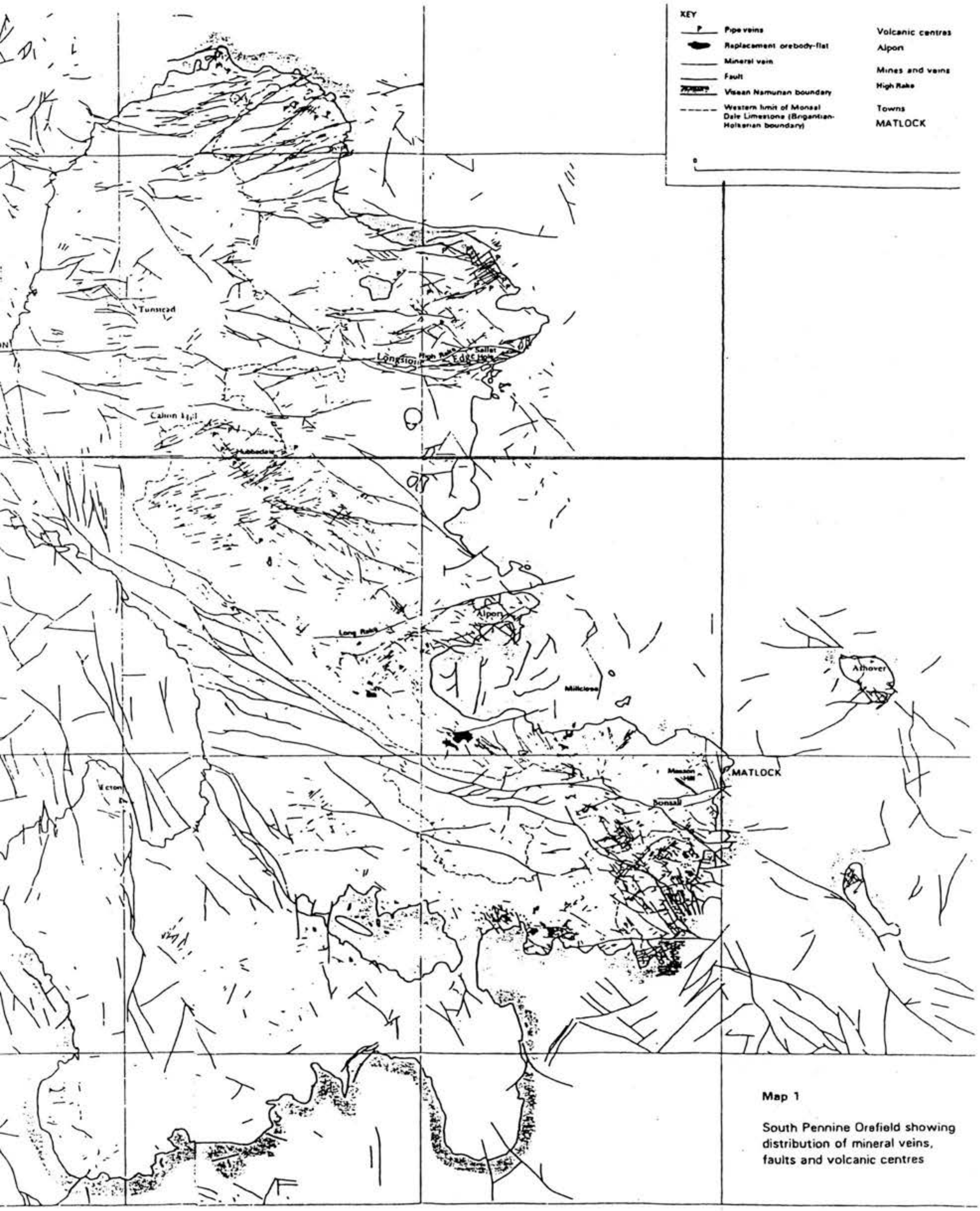

Fig 8 Map of the south Pennines orefield and the distribution of mineral veins (Plant and Jones 1989).

limestone outcrop and in the small inliers of Ashover and Crich. The three gangue minerals have became of more economic importance than lead, although large reserves of the latter undoubtedly exist. The gangue ores were considered worthless until fluorspar was required for use as a flux for the steel hearths of nearby Sheffield, during the second world war. They were initially taken from the old waste heaps lying along the sides of the worked out rakes. Later mining for fluorspar commenced in the old lead workings at Glebe Mine (SK 224 764) and Ladywash Mine (SK 218 778) and in more recent workings at Sallet Mine on Longstone Edge (SK 215 736).

Fluorspar with a calcium fluoride content of 60% or more was in demand as a flux in steel-making but if the ore exceeded 85% fluorspar content, it was of value for use in the non-ferrous metal and ceramic industries. This mineral was obtained from the waste heaps of the old lead workings at Bradwell, Youlgreave, Nether Haddon and Longstone Edge. In each of these localities, there were many cases of lead poisoning in the cattle and sheep grazing near the excavations. Glebe Mine at Eyam (SK 224 764) was a principal collecting and preparation centre with an output of 8,000 tonnes of fluorspar annually and the farm by the mine was surveyed extensively to determine the scale of pasture contamination.

Barytes or "cawk" as this mineral was known in Derbyshire, was also gained from the old waste heaps. It is used for paint manufacture, a filling material in the paper and textile industries, toothpaste and in drilling operations for oil and gas.

Calcite is the commonest gangue mineral and of the least value, being used commercially for terrazzo floors, wall surfacing and for the white lines painted on roads.

Figure 9 and 10 illustrate two commonly found forms of galena. Fig 9 shows massive vein galena deposited between layers of barytes. Fig 10 shows the more commonly found brecciated ore together with calcite and barytes. Fig 11 shows the banded form of the cream coloured barytes which is usually in a non - crystalline form. Barytes occasionally occurs in imperfect crystals - the so-called 'cockscomb' form. Fig 12 shows 'cockscomb' crystals on barytes. Fig 13 shows the translucent cuboidal crystals of fluospar.

In 1965, a large benefication plant was built at Stoney Middleton (SK 234 752) for the treatment of fluorspar and barytes. This gave an impetus to the excavation and the scale of disturbance in the area. Bramley (1990) described the scale of the operation. Some 340,000 tonnes of ore were processed annually and half of this material was bought from 'tributers' or independent contractors who had obtained the ore by excavating old workings on rakes throughout the orefield. The world demand for fluorine compounds has increased for medical and optical use, for the numerous new organo-fluorine compounds and also for use in propellant gases.

FIGURE 9 Ore. Galena with calcite and barytes. Galena is the most important ore of lead.

FIGURE 10 Ore. Brecciated ore with galena, calcite and barytes. An average yield of galena was about 5% but veins were worked with lower yields.

FIGURE 11 Ore. Banded barytes. This ore of barium once discarded is now in demand for paint and paint manufacture and also for drilling.

FIGURE 12 Ore. Crystals on barytes with fluorspar. The small imperfect crystals of barytes produce the cockscomb form shown here.

FIGURE 13 Ore. Crystal cubes of pure fluorspar. This ore was previously discarded but the modern gaining of this ore is all important.

C. *THE EXTRACTIVE INDUSTRIES*

In the EMR, the extraction of coal, gravel, limestone, the vein minerals including lead ore, fluospar, barytes and calcite have all affected agricultural practice.

The Yorkshire, Derbyshire and Nottinghamshire coal field was the largest and most productive in the UK. Fluorosis of grazing animals was of importance in the region as a result of the burning of locally produced poor quality coal and also as a consequence of the use of this coal for the calcining of ironstone in one area of Leicestershire.

The huge demand for gravel after the second world-war promoted extensive extraction from the massive pebble beds of the Middle Trent valley. The reclamation of the lagoons for agricultural purposes by filling them with pulverised fuel ash became a feature of the Trent valley and its confluences.

Limestone quarrying has taken place since Roman times and has been required for building and for making mortar and cement. There has been a considerable increase in production from fewer larger quarries as the demand for aggregate for roads has increased. The quarrying of limestone resulted in a nuisance to nearby farmers from wind blown dust but was not associated with any specific disease enquiry.

The mining of lead ore however, and the associated dressing and smelting processes, caused extensive and long-term pollution of large areas within the borders of the Carboniferous Limestone and its eastern edge.

Lead ore (PbS or galena) has been worked in Derbyshire since before Roman times but the gaining of this ore is now of little importance.

The earliest recorded date known is 81 AD taken from an inscription on a 'pig' or ingot of lead, but undoubtedly there were workings long before this (HMSO 1979).

Mining for lead reached a zenith of production between 1850 and 1870. During these years, 9% of the lead production of the UK came from Derbyshire.

D. *THE EXTRACTION AND DRESSING OF LEAD ORE*

The mined ore was dressed as near as possible to its source. Rich lumps of ore were picked by hand and the remainder hammered by hand to pea-sized pieces. These were agitated and sieved in tubs of water and the lighter gangue minerals were skimmed off and in early times, were discarded. The washed ore was then raked over a long inclined trough in a strong flow of water - the process termed 'buddling'. The heavy lead fines were left at the bottom. Up on the heights of the limestone plateau, it was difficult to find a copious supply of water near enough to the large rich veins. Working and reworking of the hillocks of discarded material resulted in further local contamination.

E. *THE SMELTING OF THE ORE*

Lead smelting has been carried out in Derbyshire for over three thousand years and has had an enduring effect on the landscape and soil. The rakes, some of which are now visible from far away as bare rock scars because of the damage to the thin, adapted vegetation, remain as major features of the landscape.

The other striking feature of this landscape which remains are the long lines of trees planted along the length of worked-out rakes. This planting was carried out in the last century and trees extend for many metres. The reason for this planting may have been to make use of the land and to shelter livestock, or it may perhaps have been a method to mark ground that was dangerous to animals.

Studies of these past smelting operations continue to be made and have immediate implications concerning the persistence of heavy metals and their effect on the survival of certain botanical species. The known consequences of the deleterious effects on animals and plant have restricted plans for future land use. These problems arise not only within the ore field but also around its periphery where numerous old smelting sites are found (Wild et al 1984).

The smelting of lead progressed through several stages. The Romans used small hearths made of stone blocks and used manually worked bellows. Until the 16th century wind-dependant boles were developed in Derbyshire and in the more northern ore fields. Later, water-power was used for creating forced draughts. However, boles were still in use in Derbyshire until late in the sixteenth century. A major advance in smelting was the introduction of coal as a fuel by the London Lead Company in 1735 to fire the new reverberatory furnaces. There was then no longer a need to find a site with water-power and the charges of ore became larger.

The wind-blown bole was a large hearth burning wood and some peat, sited on the crown of a west facing hill or steep escarpment facing the prevailing winds. A bole was most often built on a Millstone Grit edge lying to the east of the ore field (Kiernan and Van de Noort 1992). In Derbyshire, this was the principal means of smelting lead from the 12th century until late in the 16th century. The ore was carried in panniers by pack-horses and mules and the paths can still be recognised, sometimes from lead contamination probably resulting from spillage (Ineson 1983). If the wind were strong enough, a charge of ore and fuel would take two days to burn at a temperature of 600-800o C, consuming 30 tons of kiln-dried wood and producing 18 tons of lead from 40 tons of dressed ore.

The methods of smelting galena involve a complex series of reactions termed the roast-reduction process. This may be simplified into the two stages as follows:-

a) first the roasting of ore in the air

$2\ PbS + 3\ O_2 = 2\ PbO + 2\ SO_2$ $2\ PbO + PbS = 3\ Pb + SO_2$

$2\ PbS + 4\ O_2 = 2\ PbSO_4$ $PbS + PbSO_4 = 2\ Pb + 2\ SO_2$

b) second stage treatment of slag in a reducing atmosphere

$$PbO + CO = 2\ Pb + 2\ CO_2$$

The reverberatory furnace or cupola, burnt coal in a separate box and the heat was reflected i.e. reverberated on to the ore. In the cupola, temperatures could reach 1100-1200o C.

The second stage took place in a slag hearth and was a reduction process and this recovered the lead from the "grey" slag left from the first oxidation. Charcoal and later coke, were burnt in a shaft and the carbon monoxide and carbon reduced the oxides, sulphides and sulphates of lead. A floating 'black' slag was produced which was tapped off the underlying liquid metal. Volatilisation of lead occurred at both stages of smelting. Estimates have been made of the percentage of lead lost to the atmosphere. Lead was lost from these industrial sites and contaminated the surrounding areas. Colbourn (1976) measured the lead contamination of the soil around the rakes, bole hills, the site of ore sieving and smelters. Table 3 shows the lead distribution in top soils taken at points up to 2,000 m from the source of pollution of sites where lead poisoning had been diagnosed in grazing animals.

History of site	Distance from source (m)						
	0 - 100 - 250 - 500 - 750 - 1000-2000						
A. ***Tideslow*** (rake)	11000	1990	610	-	-	-	
B. ***Great Hucklow*** (rake and smelter)	14100	4000	2300	2200	570	760	-
C. ***Ladywash*** (spoil heaps and smelter)	18730	860	540	570	760	-	-
D. ***Brook Bottom*** (ore dressing)	15400	15400	1625	490	-	-	-

TABLE 3 The mean distribution of lead in top soils (μg Pb/g) around lead mining site (Colbourn 1976). Background lead vales for limestone sites such as A and D are 125-215 μg Pb /g and for gritstone sites B and C, 75-180 μg Pb/g.

The Application of Geochemical Reconnaissance to Agriculture

A. *INTRODUCTION*

The optimum range for most of the trace elements found in soil is narrow and serious deficiencies or excesses of these elements can result in the death, or the unthriftiness of animals grazing pasture grown on such soils.

Stream sediment surveys had previously been used for mineral exploitation but work of the Applied Geochemistry Research Group (AGRG) confirmed that certain relationships existed between regional biochemical data and animal health. This indicated that other suspect areas required detailed investigation (Webb 1964; Thornton and Webb 1970; Webb et al 1971; Thomson et al 1972).

Geochemical reconnaissance is based on the widespread extensive sampling of the sediments of tributary streams. The sediment is chosen as it is similar to a composite sample of the soil and rock taken upstream from the site of sampling. Fig 14 shows the lead content of sediment taken from the streams around the Carboniferous Limestone "dome" of Derbyshire. This map was produced by AGRG in 1967 and was to prove of value in tracing sources of pollution and in later investigation into the source of lead in poisoning enquiries. The map of the molybdenum content of the same catchment area is shown in Fig 15.

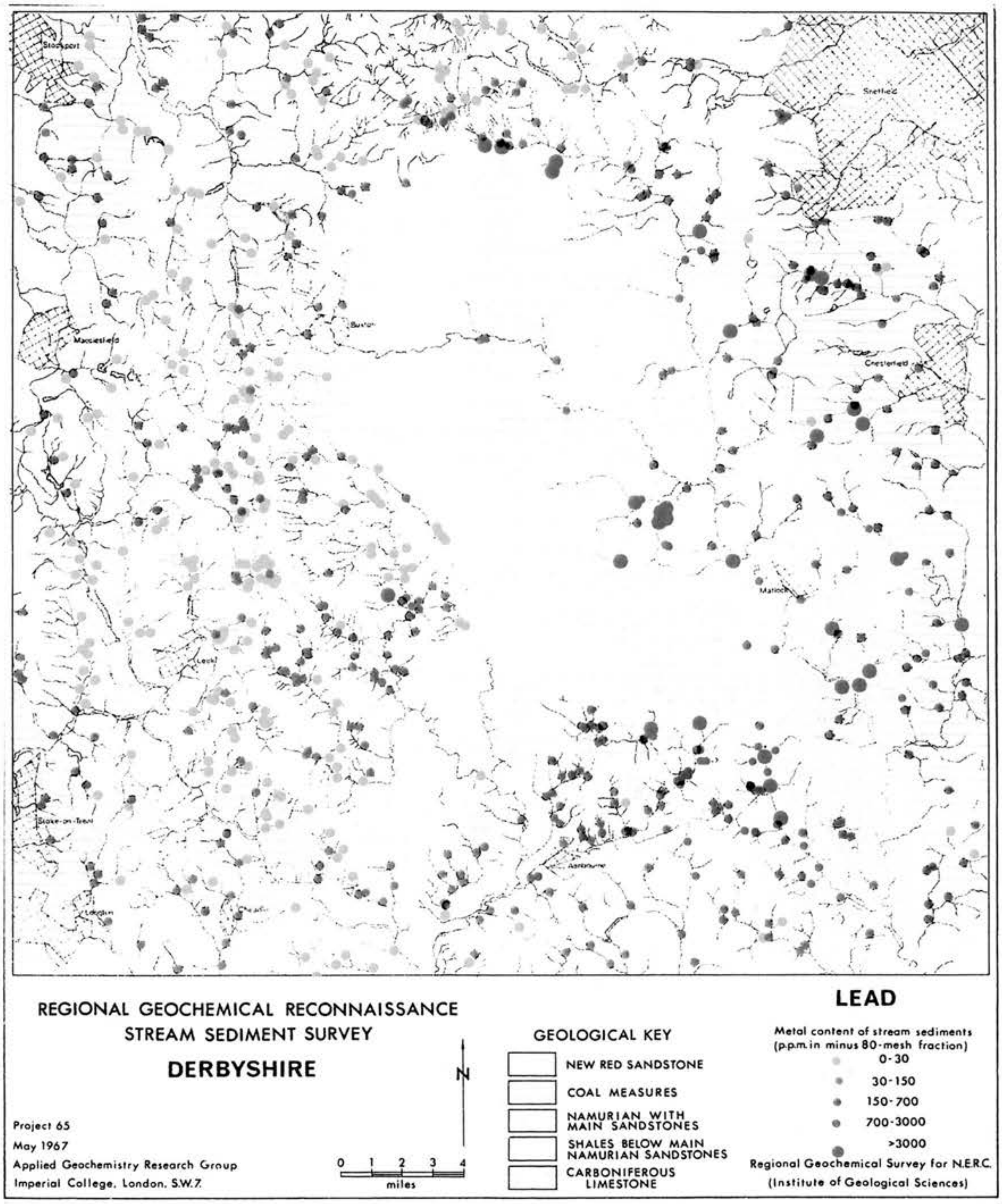

FIGURE 14 The lead content of stream sediments in Derbyshire. The area of the Carboniferous limestone possess few streams.The streams draining the imestone to the east show the high values of lead (Nichol et al 1970).

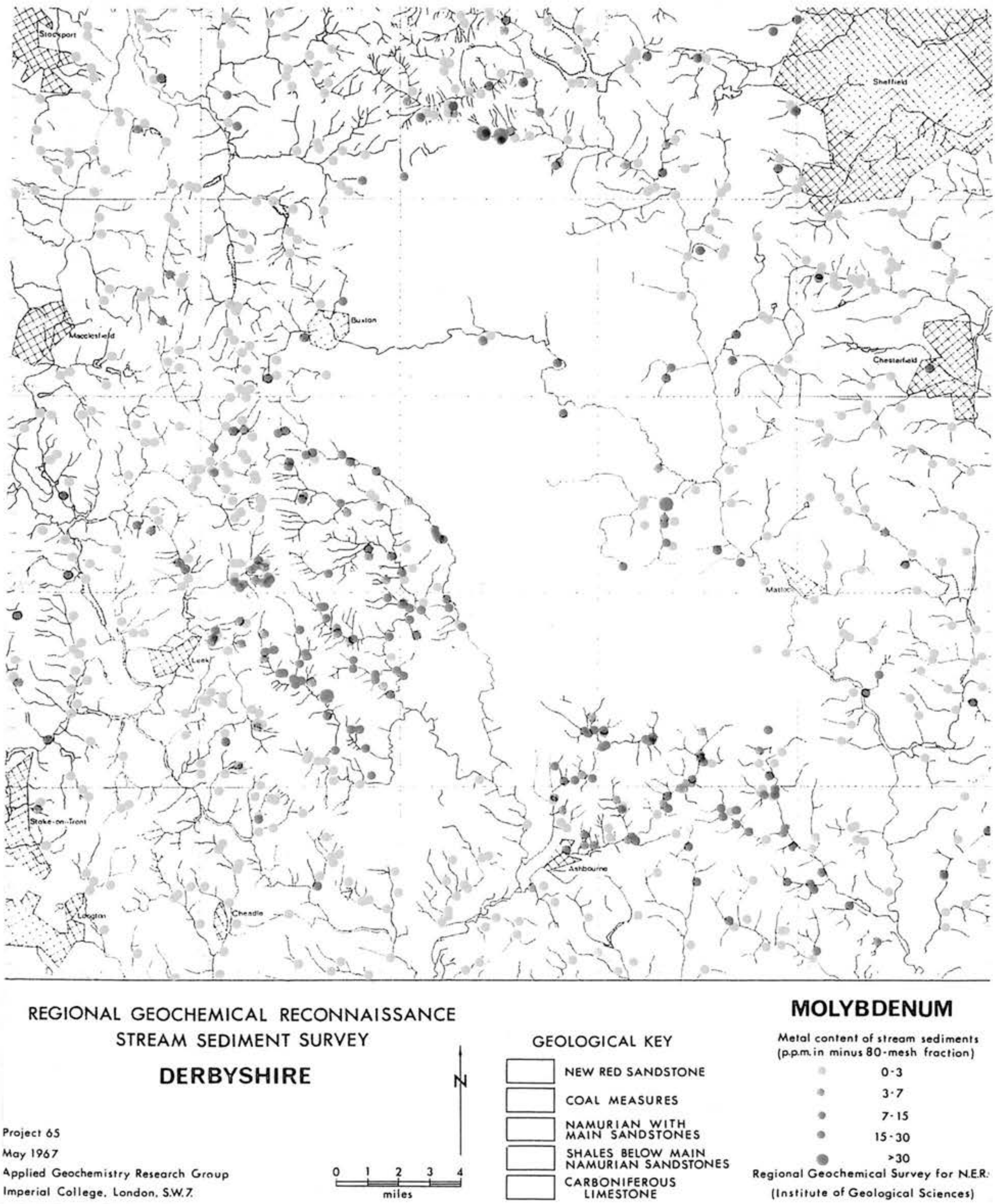

FIGURE 15 The molybdenum content of the streams in Derbyshire. The scarcity of streams on the Carboniferous limestone is shown and the concentrations of molybdenum in the streams draining the limestone to the west in the Onecote and to the south in the Asbourne area (Nichol et al 1970).

Stream sediment is relatively stable and consists of clastic material, made up from fragments of pre-existing rocks transported to the point of deposition. Apart from their origin, sediments are subject to certain variations introduced by factors such as selective deposition during transport, precipitation of iron and manganese oxides which "scavenge" elements such as cobalt and also adsorption on organic matter. Such variables can be reduced by choosing a fine fraction of sediment and by avoiding organic rich stretches of the stream. The AGRG arranged for such samples to be collected at a mean density of 1 sample per sq mile (2.6 km sq).

The analytical data were processed by computer and maps were prepared by laser-plotter. The method proved to be inexpensive, simple to organise and rapid in execution. However, the interpretation of the maps is complicated by many factors which influence the chemical relationships between stream and soil, soil and plant and plant and animals. The drainage area chosen must be sufficiently big and such a large scale does not allow field-by-field evaluation nor the detection of small areas of toxic or deficient soils. As the limestone "dome" of Derbyshire possesses few constant surface streams, extensive sampling was not possible. Also, this survey method cannot distinguish between the different soil series occurring in the catchment area.

B. *GEOCHEMICAL RECONNAISSANCE METHODS AND ANIMAL HEALTH*

The first collaboration by Sutton Bonington VIC with AGRG commenced in 1966. Initially, trials were designed to extend the application of geochemical reconnaissance to the agriculture of the EMR. Severe copper deficiency had been recognised clinically on farms in

Derbyshire and in north Staffordshire, the neighbouring county to the west, and was found most commonly in young dairy stock during their first or second grazing season. The condition was known to be of economic importance (Allcroft 1952). Injections of copper resulted in marked clinical improvement although repeated treatment was often indicated on the farms where the condition was severe.

In 1965, a wide-scale geochemical survey was carried out by Imperial College workers (later to become the AGRG) over 800 square miles (2000 ha) and demonstrated well-defined molybdenum anomalies in an area of 10 square miles (16 ha) in the vicinity of the town of Ashbourne in Derbyshire and the village of Onecote in Staffordshire (Webb, Thornton and Fletcher 1968). The anomalous patterns of molybdenum were found to correspond to the distribution of Namurian and Visean black marine shales.

Thornton et al (1972) carried out blood copper analyses on cattle from 26 farms within the molybdenum anomalous area of 10 square miles (16 hectares) found by Webb et al (1968). The Onecote farms were small and poorly drained with a high rainfall at altitudes of over 1000 ft (300 metres). The Ashbourne farms were more successful as they were situated at lower altitudes and reared more thriving stock. The lowest blood copper values were found in cattle of 11 months to 30 months of age. The presence of the moylbdeniferous soils was related to the local variations in geology and parent material and was particularly affected by drift cover i.e. the deposits and smears left after the retreat of the glaciers. Later, Clegg et al (1983) working from Sutton Bonington VIC, found that the incidence of hypocupraemia was greater in Derbyshire than in the neighbouring counties of Leicestershire and Nottinghamshire. Young stock in Derbyshire showed the lowest blood concentrations of all groups in the three counties. These young animals would have been left to graze until late in the season and would have received little supplementary feed.

Serious enquiries concerning heavy metal contamination of agricultural land in the EMR commenced in 1970. Nichol et al (1970) completed the Regional Geochemical Reconnaissance of the Derbyshire Area which indicated extensive contamination by heavy metals resulting from past smelting and mining activities. The results showed the usefulness of stream sedimentation reconnaissance as a means of detecting larger areas of contamination. Particular stream sediment anomalies were later delineated on a greater scale, as were areas known to be hazardous to stock (Clegg and Rylands 1966). Colbourn (1976) described a mineralised area of 250 sq km in north Derbyshire. Soil samples containing several hundred to several thousand ppm of lead with values as high as 3% were found close to old workings.

Stream sediment surveys carried out elsewhere in the UK indicated correlation between the incidence of deficiency diseases and the map distribution patterns of cobalt, manganese and selenium (Webb 1964; Thornton and Webb 1970).

The studies carried out by the AGRG indicated the ability of geochemical reconnaissance methods to be used in the delineation of multi-element distribution patterns on a regional basis. It was recognised that the findings would be of use to both veterinary workers and agriculturists. Such methods would help in making decisions concerning animal management and plans for the use of land.

Nichol et al (1970) assessed the results of the geochemical reconnaissance of the Derbyshire area. They found that the stream reconnaissance method provided a unique source of information to add to existing knowledge obtained by conventional survey methods. The method was reliable and information obtained from the study was of value. Discussion of the geological applications and the prospects for its use in future mineral application was followed by a separate section on the agricultural applications.

Webb et al (1966) had previously considered the value of such stream reconnaissance in determining the selenium status of soils in parts of England and Wales. Abnormal concentrations of selenium were found in some streams but in the case of Derbyshire, these levels were not associated with known agricultural problems (Webb et al 1968). It was considered that there was a strong correlation between the regional distribution of molybdenum in stream sediments and the incidence of induced hypocuprosis. The authors demonstrated raised Mo values in soils derived from marine shales and also in herbage grown on these molybdeniferous soils.

Alloway (1973) attempted to correlate pasture molybdenum values with the incidence of "swayback" of lambs in north Derbyshire, Northamptonshire and Denbighshire and concluded that in some cases, a molybdenum induced hypocuprosis may be a contributory factor in the occurrence of the disease.

Suttle et al (1984) suggested that soil ingestion might impair copper absorption in sheep by trapping sulphur as a heavy metal sulphide, such as FeS, which then releases the sulphide in the acid conditions of the abomasum. The later realisation that there is antagonism of the iron present in ingested soil to copper metabolism (Suttle 1986), is of particular interest in view of the early reports of the pioneer worker Miss C M Ford of Sutton Bonington. Ford (1956) described the marked variations in the quality and quantity of the herbage in the EMR and associated these with the availability of iron and manganese and resulting effects on the fertility of grazing animals in plants. This worker observed the effects of the flushes of iron that occur in natural sources of drinking water in north Derbyshire and considered that iron values of 0.4 ppm would result in hormonal derangement of those cattle that drank it. Water values as high as 8 ppm were found occasionally in this area (Ford 1960). This redoubtable worker on cattle infertility also indicated the dangers of excessive manganese intake, as well as the recognised deficiencies of this element (Ford 1973).

An evaluation was made of the survey for its role in demonstrating the massive concentrations of lead lying towards the east of the north Derbyshire ore field (Fig 14). Taylor (1968) wrote a classical study of the heavy pollution present in this area and particularly the area known as Eastmoor. The concentrations of lead were shown to coincide with the sites of former lead mining and smelting.

The studies carried out by the AGRG indicated the ability of geochemical reconnaissance methods to be used in the delineation of the distribution of many trace elements on a regional basis. The findings have proved to be of benefit to veterinary workers and to agriculturists. The methods have allowed decisions to be made concerning herd and flock treatments, liming, choice of fertiliser and perhaps decisions on pasture management. The Wolfson geochemical atlas of England and Wales was published in 1978 (Webb et al 1978) and based on the sampling of 119,000 square miles. Later uses of this atlas included studies of human mortality and also the distribution and determinants of human populations (Shaper 1979).

The Regional Geochemical Reconnaissance of the Derbyshire Area (Nichol et al 1970) carried out by the AGRG indicated the extensive contamination by heavy metals resulting from past mining and smelting activities. The usefulness of stream sedimentation reconnaissance as a means of detecting large areas of contamination was clearly shown and particular sediment anomalies were later to be studied on a greater scale.

IV. LEAD POISONING

Introduction

This chapter describes the history of lead poisoning of animals in the EMR and the investigations into the cause and extent of each of the losses. The discussion concerns the value of these enquiries in relation to animal and human health and land use. The earliest records of animal losses are given and descriptions of the circumstances under which more recent poisonings have occurred. The work of the Sutton Bonington VIC is described together with the valuable collaboration which took place with workers from other fields. Table 4 shows the sequence of the principal events in the past investigations of losses in grazing animals associated with the peculiar conditions found in the ore field and in the surrounding areas affected by smelting. Historically, Leigh (1700) and Farey (1811) wrote about the illness of grazing animals in Derbyshire. Their descriptions of the clinical signs are given in Appendix A.

Lee and Tallis (1973) studied the historical aspects of lead pollution in the UK using moss specimens from botanical collections as indicators. The samples from north Derbyshire were amongst the highest lead values found and corresponded with the period of greatest extraction of ore during the 18th and 19th centuries. Present day values remained high and were associated with current reworking of waste tips for fluorspar and with other industries. Lee and Tallis (1973) also determined the accumulated lead values found in peat deposits to the north of the ore field. They found evidence

17 & 19th century. Knowledge of poisoning ("roaring") of horses and of contaminated ("belland") pastures(Leigh 1700; Farey 1811)

1924 Reports of crippled lambs on Brassington Moor (Gardner 1924)

1937 Lead tissue values of lambs with "swayback" (Innes and Shearer 1940)

1962 Investigations into the cause of lamb losses (Clegg and Rylands 1966)

1964 Stream geochemical reconnaissance of areas of metal mineralisation (Nichol et al 1970)

1966 Studies of pollution from smelting sites on Eastmoor (Taylor 1968)

1970 AGRG: Stream geochemical reconnaissance and agriculture (Colbourn 1976)

1974-76 AGRG: Studies of lead uptake by grazing animals on 12 farms (Thornton et al unpublished data)

1978 Publication of geochemical reconnaissance atlas of UK (Webb et al 1978)

1978-79 Investigations into soil contamination of silage and poisoning of dairy herds (Clegg and Tasker - unpublished data)

1982 Lead levels in Sheffield milk supply: Survey of Lead in Food (MAFF 1982)

1982 Farm demonstrations of methods of improved silage making (Tasker, C - personal communication)

1982 AGRG and Westminster Hospital Medical School: Study of lead uptake by cattle in the old lead working areas. (Thornton, Kinniburgh, Clegg, Lewis, Barltrop and Strehlow - unpublished data)

1984 Study of heavy metal contamination of the Eastmoor and the implications for human health (Wild et al 1984)

1996 Peak Park Planning Board enquiry into the extent of lead polluted ground

TABLE 4 Enquiries and publications pertaining to lead poisoning in Derbyshire.

of pollution from the time of Roman smelting activities and the maximum values from the time of the immense growth of the lead industry in the late 19th century.

Gardner (1924), a reader in Biochemistry of the University of London, spent his holidays on a farm near Brassington (SK 238 542) in north Derbyshire. Gardner enquired about the risks to horses grazing in the area and about the term 'belland' used to describe the illness. He believed that the word was of Anglo-Saxon derivation from the verb *bellan* to roar. Gardner also gave the first description of a local disease of lambs affected with 'ricketty' backs.

The Sutton Bonington VIC in common with all VIC's in the UK was frequently involved in the investigation of lead poisoning from many other sources. Table 5 and Table 6 show the number of cases of poisoning in cattle and sheep in the county of Derbyshire, in England and Wales and the total number of cases in the UK from 1975 to 1988 and from 1975 to 1995.

Clegg (1978) described the historical reasons for the paramount importance of such enquires in Derbyshire and related this to the position of the ore field and its industries. Hunt (1975) noted the peculiarities of this mining area compared with other regions. The Mendip ore field is small in extent measuring only 6 by 8 km. The mines of the Lake District were entered byadits 300m above sea-level and resulted in little surface contamination. Similarly, the mines of the north Wales ore field were situated in the steeply glaciated valleys with only a little local contamination. The north Pennine ore fields are similar in many ways to the ore field of Derbyshire and are situated on high moorland with grazing sheep at risk from poisoning.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Derbyshire													
1975 - 88	5	6	6	16	48	52	24	22	17	7	4	6	209
1975 - 95	9	11	17	21	60	63	38	26	22	10	10	8	291
England and Wales													
1975 - 88	138	172	189	270	458	411	294	160	103	103	110	113	2530
1975 - 95	175	214	259	327	624	537	371	204	132	125	234	147	3311
United Kingdom								**TOTAL**	1975 - 1988				**3387**
									1975 - 1995				**4373**

Table 5 VIDA diagnoses of cattle poisoning due to lead for Derbyshire, England and Wales and the UK (1975 - 1988 and 1975 - 1995).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Derbyshire													
1975 - 88	-	1	1	3	7	14	1	1	-	-	-	1	28
1975 - 95	-	1	1	7	14	17	3	1	-	1	2	1	47
England and Wales													
1975 - 88	-	3	4	8	21	20	1	-	4	3	1	1	66
1975 - 95	2	4	6	12	34	28	5	-	5	3	4	1	104
United Kingdom								**TOTAL**	1975 - 1988				**86**
									1975 - 1995				**128**

Table 6 VIDA diagnoses for sheep poisoning due to lead in Derbyshire, England and Wales and the UK (1975-1988 and 1975-1995).

Hunt (1975) working at Sutton Bonington VIC determined the blood lead values of cattle in all the parishes of the Peak District. Representative samples taken from herd blood tests for Brucellosis were analysed. In this exhaustive and valuable work, Hunt was able to relate high blood lead concentrations of the dairy herds within the bounds of a parish, to the mining history, the scale of workings and ground disturbance within many of the most extensively contaminated areas. Fig 16 shows the distribution of these parishes within the ore field. Ineson (1983) described the geochemical and botanical features related to the presence of heavy metals in this area of the Pennines and the circumstances leading to contamination of pasture with lead.

The expertise gained by Sutton Bonington was to prove of value in later investigations. The poisoning of cattle herds in the UK in 1988-1989 occurred after a shipment of maize gluten imported from the Netherlands had been contaminated by lead ore in the holds of a ship. The incorporation of the meal into 30,000 tonnes of animal feed followed and this was distributed to 2,000 farms in the midlands, south Wales and the south-west of England (Annual Report of the State Veterinary Service 1989). Sutton Bonington VIC carried out a total of 10,000 analyses for blood lead concentrations in cattle from poisoned herds. Repeated samples were taken until the farms were released from the restrictions that had been placed on them.

All lead estimation of tissues recorded in the early part of this work were carried out by the Fischer Leopodi method of Winter et al (1935) modified by the CVL micro-determination method of Eden and Green (1940). From 1986, lead estimations of tissues were carried out using a graphite furnace atomic absorptiometer (GBC 902) shown in Fig 6.

Nichol et al (1970) assessed the results of the regional geochemical reconnaissance of the Derbyshire area using two criteria. The first was that the stream reconnaissance method provided a unique source of information to add to existing knowledge obtained by conventional survey methods. The second was the reliability and the practical value of information obtained from such a feasibility study. Discussion of the geological applications and the prospects for its use in future mineral exploration was followed by a separate section on agricultural applications.

Webb, Thornton and Fletcher (1966) had previously considered the value of such stream reconnaissance in determining the selenium status of soils in parts of England and Wales. Abnormal concentrations of selenium were found in some streams but in the case of Derbyshire, these levels were not associated with known agricultural problems (Webb, Thornton and Fletcher 1968). It was considered that there was strong correlation between the regional distribution of molybdenum in stream sediments and the incidence of induced hypocuprosis. The authors demonstrated raised Mo values in soils derived from marine shale and raised Mo values in pasture herbage grown on these molybdeniferous soils. The authors found no correlation with swayback and manganese deficiency.

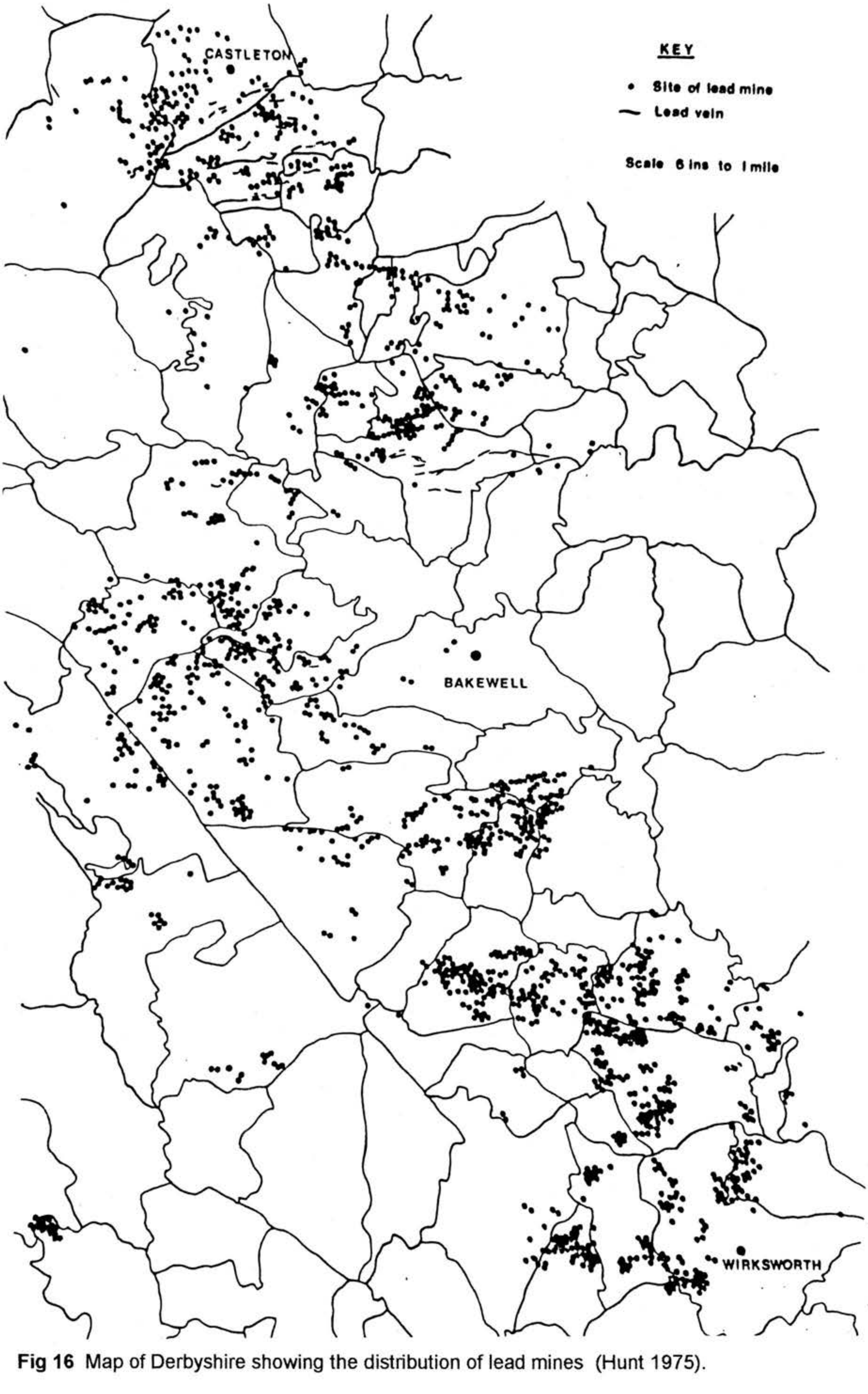

Fig 16 Map of Derbyshire showing the distribution of lead mines (Hunt 1975).

Evaluation was made of the survey for its role in demonstrating the massive concentration of lead in the east of the area (Fig 14). This coincided with the former base-metal mining and smelting activity in the area and added to the observations and the importance of the classical studies of heavy metal pollution on Eastmoor (Taylor 1968).

The first investigation by Sutton Bonington VIC into the poisoning of lambs (Clegg and Rylands 1966) on Tideslow Farm (SK 152 782) was extended to include further studies of the lamb losses and also those occurring in cattle. Collaboration took place with geologists, geo-chemists, botanists, soil scientists and industrial archaeologists. A further investigation is described which resulted in the discovery of an ancient ore washing plant and others describe the lead poisoning of dairy herds as a result of contamination of pastures. In the first herd, gross soil contamination of silage was due to the disturbance of the fields and the messy way the grass was collected. In the second herd, poisoning the growing grass was polluted in the field by lead fume from an industrial source and silage made from these fields proved to be toxic to cattle.

Lead poisoning of mute swans (*Cygnus olor*) was investigated by Sutton Bonington VIC following the initial report of losses in birds from the river Trent (Simpson, Hunt and French 1979) and the publicity which followed.

Clinical Signs of Lead Poisoning

Signs of acute poisoning in cattle are hyper-irritability, convulsions, blindness, twitching of muscle masses, salivation and grinding of teeth. These signs may be very brief and death sudden (Christian and Typhonas 1971; Osweiler et al 1973). In cases of more chronic poisoning, cattle appear dull and unthrifty. The twitching of skin muscles may be marked. An anaemia may develop within two months of the commencement of poisoning - or may not occur at all (Allcroft 1951; Logner et al 1984). Preece (1995b) has described the appearance of clinical signs in cattle immediately after turnout to pastures in spring after the period of housing and associated this with the release of accumulated lead from the tissues due to increased muscular activity and circulation.

The chronic form of lead poisoning of sheep has been found under field conditions on contaminated pasture. It is characterised by stiffness, lameness and ill thrift (Stewart and Allcroft 1956; Butler et al 1957; Clegg and Rylands 1966). Clegg and Rylands described the kidney lesions found in lambs (Fig 17) and the lameness associated with an osteoporosis previously found by Butler et al (1957). In experimental poisoning of sheep, sterility and abortions have been observed (Allcroft 1951; Sharma and Buck 1975). Carson et al (1974) reported impaired responses by sheep to auditory stimuli after they had been given 100 mg of lead per kg body weight for only nine days and slow learning behaviour of lambs that had been exposed to lead *in utero.*

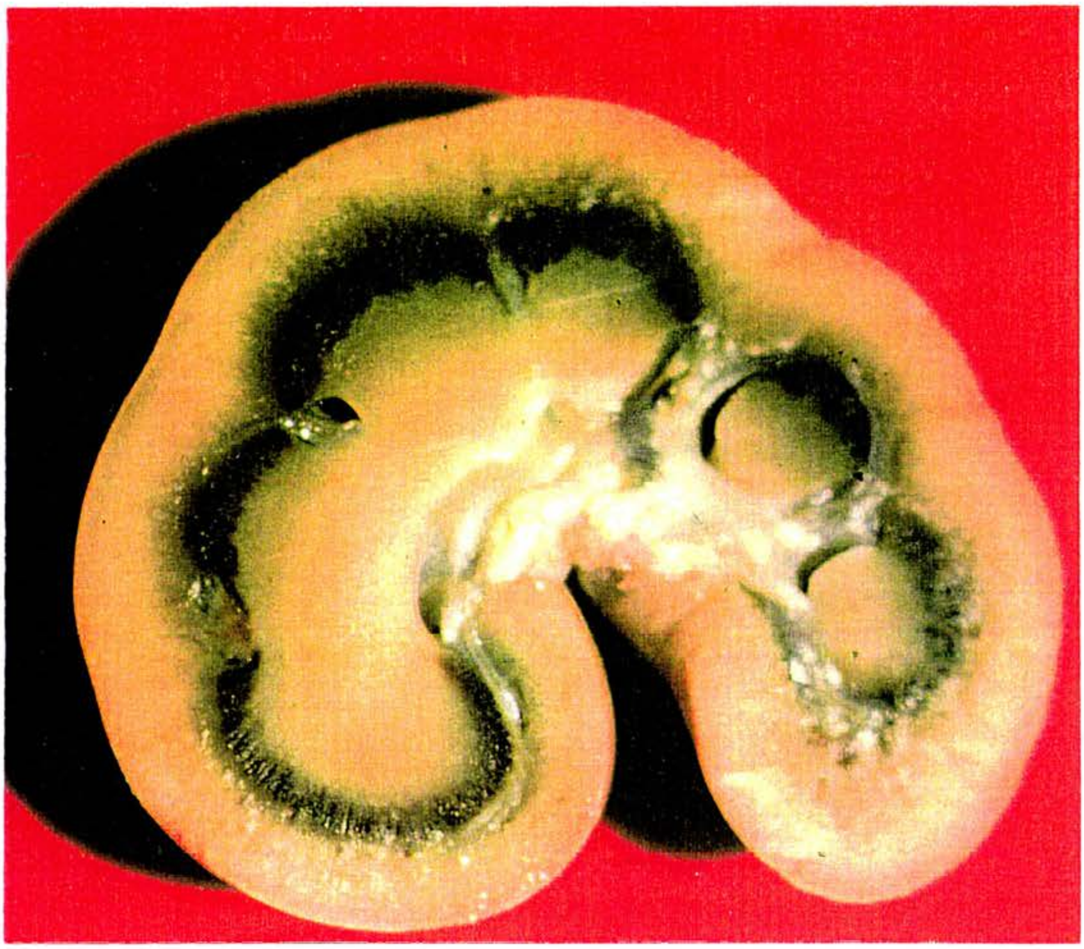

FIGURE 17 Section of the kidney of a 6 week old lamb showing lesions of lead poisoning with the characteristic haemorrhage into the arcuate zone.

Lead poisoning of horses is usually found as a chronic intoxication and may show differing clinical signs (Dollahite et al 1975 and 1978; Willoughby et al 1972; Wilson et al 1979). Laryngeal hemiplegia and pharyngeal dysfunction is most commonly recognised and may be sudden in onset. Seawright et al (1983) compared the dysfunction with the consequences resulting from the chronic

peripheral neuropathy produced by experimental poisoning of guinea pigs(Fullerton 1966).

The classical sign of chronic lead poisoning in horses follows this paralysis of the larynx and causes a loud respiratory noise known colloquially as "roaring" and can be evinced by exercise. Knight and Burau (1973) produced the condition over a period of months by dosing horses with 6.4 mg of lead per kg body weight. "Roaring" was the one clinical observation that was recognised in Derbyshire

and the one that was associated with the dangers of lead poisoning from certain fields. It was also associated with the nearness of industrial sites, especially smelters. Such land was said to be *bellanded* and historically such grazing was recognised as dangerous to horses (Leigh 1700). A more recent sophisticated population of incomers arrived with their ponies. They frequently learned which were the dangerous fields from the occurrence of illness in their animals - or perhaps from the prescience of the older villagers. Rylands (1971) recorded the raised tissue lead values in a pony which had grazed contaminated pasture near a lead works in north Derbyshire.

In north America, the poisoning of horses grazing in the vicinity of lead works is well documented (Aronson (1972); Burrows (1981); Burrows et al (1981); Hammond and Aronson 1964; Kradel et al (1965); Larsen (1969); Ottoboni and Kahn (1970); Schmidtt et al (1971)). Gordon (1968) reported that it was not possible to rear horses on certain pastures near to smelters. The historical aspects of the high incidence of lead poisoning caused Burrows (1981) to suggest that the horses might be regarded as sentinels to portend the likely hazard of the general environmental contamination. The raised levels found in herbage collected within 20 m of busy roads may be hazardous to horses when they are up to three times those found in herbage taken from further away (Getz et al 1977).

The death of barnyard hens was said to have been common in the ore field when birds had ingested small particles of galena. Edwards (1979) refers to the death of hens on a farm where lead poisoning of horses was recognised. The number of free-range fowls scratching in the yard became so low that *post-mortem* examinations were not carried out.

Chronic lead poisoning of dogs has been investigated on farms where lead mine waste has been used for road making. The clinical signs observed included convulsions, muscular tremors, frothing and salivation (Wardrope and Graham 1982).

Investigations

A. *LEAD POISONING OF CATTLE AND SHEEP ON THE SITE OF A MINERAL WORKING*

Lead poisoning of ruminants around the sites of mineral workings have been described in the UK and in Eire. Stewart and Allcroft (1956) described unthriftiness of lambs on land near old lead workings in the northern Pennines and Butler, Nisbet and Robertson (1957) reported lamb losses associated with osteoporosis again in lambs grazing near lead mines in the Southern Uplands of Scotland. Harbourne et al (1968) described losses in calves near old lead workings in Swaledale. Donovan et al (1969) carried out a survey of lead in grazing animals, pasture and water and Egan and O'Cuill (1969 and 1970) described the toxic hazard to ruminants and then to horses in a mining area in Eire.

Cattle and sheep deaths continued to be investigated for many years on the farm where losses in lambs had first been described by Clegg and Rylands (1966). These workers described the loss of 50 lambs of the 158 born in the spring of 1962 and of 20 of the 126 lambs born in 1963. The authors described the kidney lesions and the osteoporosis which were found. Many of the survivors were poor and crippled and the owner suffered severe financial loss in both years. Other losses followed and in December 1974, 24/31 cattle aged from six to eight months perished. Investigations continued in 1973 and trials carried out on the farm in 1976 indicated the scale of the problem of lead uptake by grazing animals.

History

The farm of 150 acres (65 ha) is crossed by the Great White Rake (SK 152 782) which is about 30 acres (12.5 ha) in extent from east to west. Figs 18, 21 and 22 show the topography of the rake and its position in relation to the farm buildings and the field walls. Across the most extensively affected fields, the rake lies in a hollow and so water-borne pollution of the land by lead was considered to be unlikely. The construction of a new road, made with spoil from the many available waste heaps lying in and by the rake, resulted in considerable disturbance and the contamination of several fields. The road was improved and repaired in the early 1960's at the time the new grassland was being reclaimed from the extensive original rough grazing present. Fig 19 and 20 show aerial photographs taken in April 1948 and March 1962. The change of the route of the improved farm road compared with the original meandering track can be seen on the first photograph. Snow has drifted against the walls on the later photograph and this clearly shows the improved layout of the fields and the extensive area reclaimed from rough grazing in the south-east corner of the farm.

Figs 23 and 24 show the site of an ancient ore crushing circle probably worked by horses pulling the large circular stone wheel. This circular area measured some 10 m in diameter and its position can still be traced by the poor growth and chlorosis of the grass. Particles of galena can readily be found in the soil within this circle.

Smaller workings exist in several fields abutting on those affected by the main rake. A geochemical survey carried out by the Department of Biology, University of Sheffield, delineated the areas where enhanced lead and zinc soil values were found (Bayliss et al 1979).

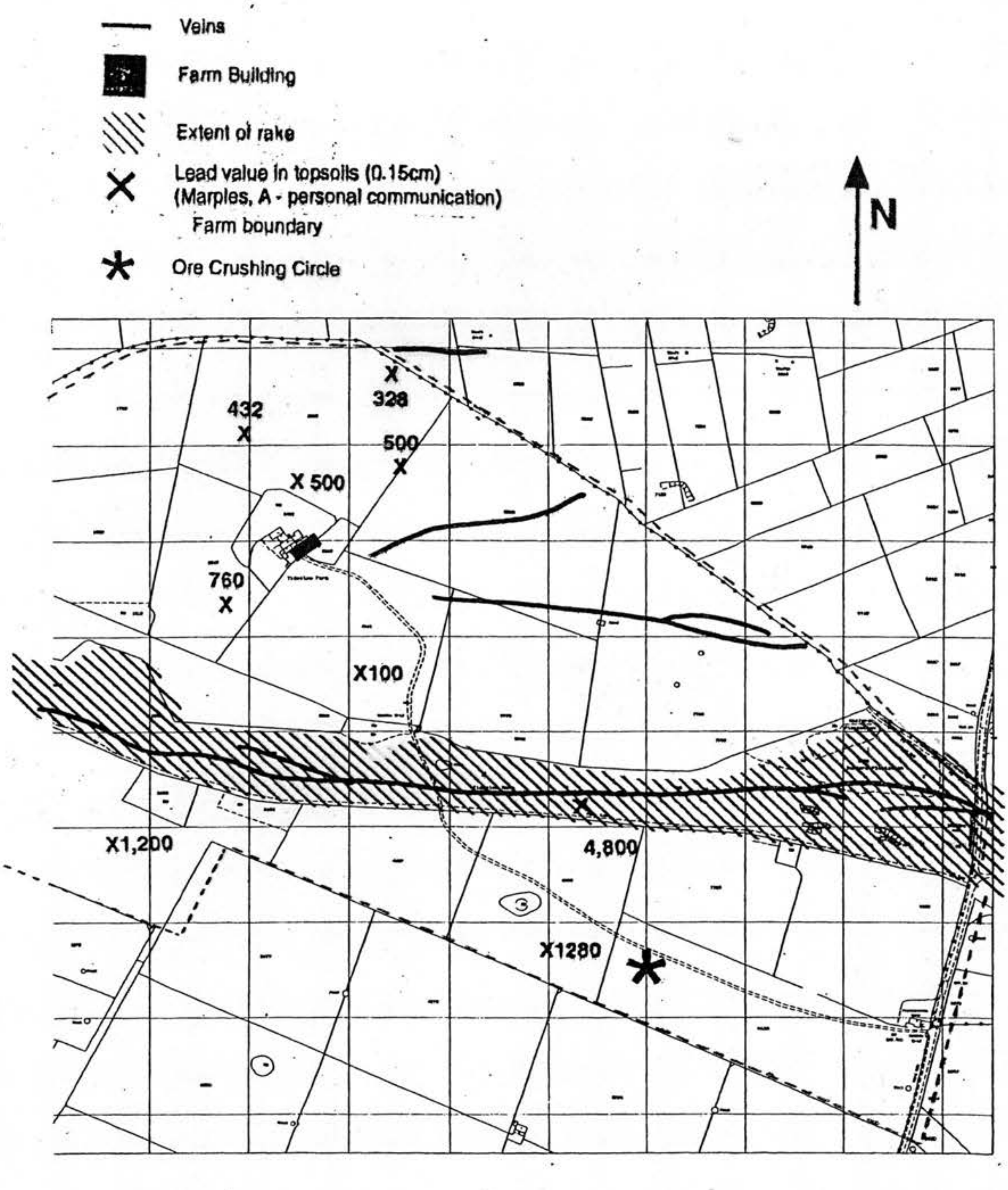

FIGURE 18 Map of Tideslow farm and the distribution of lead rakes (Scale 1:5000).

FIGURE 19 Aerial view of Tideslow farm in April 1948 . The view shows the fields in relation to the extent of the Great White Rake. The black circular structures are produced by cloud cover. © Crown Copyright/MOD.

FIGURE 20 Aerial view of Tideslow farm in March 1962 (1:8600). The extent of the Great White Rake is shown with accumulations of snow outlining the field walls. © Crown Copyright/MOD.

FIGURE 21 View of the length of the Great White Rake to the west in June 1996.

FIGURE 22 View along the length of the Great White Rake to the south of the farm in June 1996.

FIGURE 23 View of the site of an ore crushing circle June 1996.

FIGURE 24 View of chlorosed vegetation growing on the site of the ore crushing circle,

June 1996.

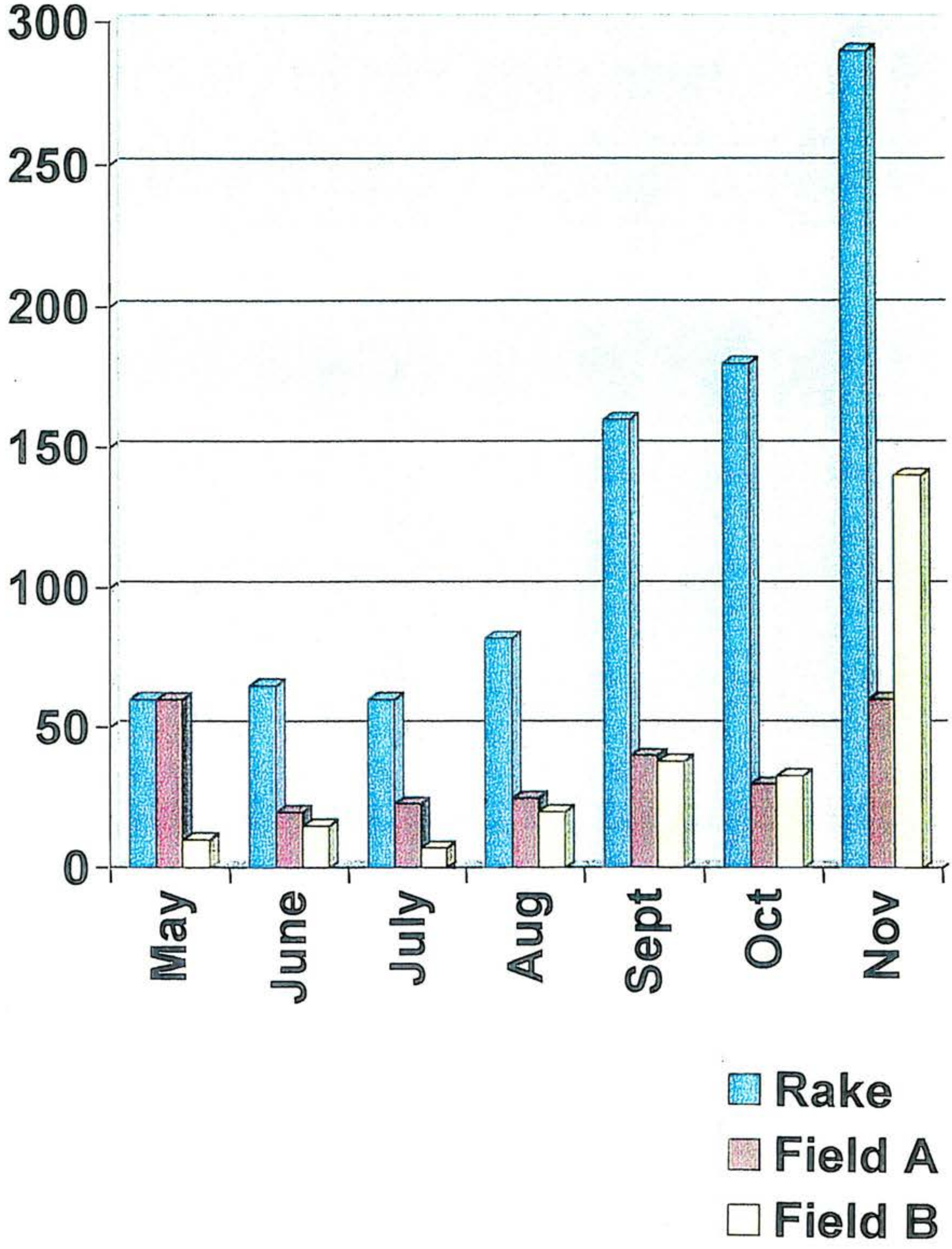

FIGURE 25 Graph showing the lead content of herbage collected from the rake and the adjoining fields on Tideslow farm from May to November 1973. Field A lies along the south edge of the rake and field B to the north (Fig 18). Lead herbage values are given in ppm/DM. (Normal ranges for herbage are 2 - 8 ppm/DM).

Results

The results of the tissue analyses of cattle and sheep dying in 1973 and 1974 are shown in Table 7. The lamb deaths investigated in 1973 and 1974 were shown to be due to lead poisoning and similar to the losses first investigated in 1962. Analyses of the tissues of two aborted lambs showed that accumulation of lead was occurring *in utero*.

The extensive deaths of cattle in 1974 were diagnosed as lead poisoning and the bone lead values in yearlings and the aged cow showed that this was chronic. The blood lead concentrations of healthy yearling cattle grazing these fields on Tideslow Farm are shown in Table 8. Of this group of 21 Friesian cross store

animals, 11 were sampled on successive occasions, first in the spring soon after they were allowed out to graze and then in the late autumn after five months at pasture. The mean lead value was the same for the whole group of 21 cattle as for the 11 paired samples from the same animals.

Table 9 and Fig 25 show the lead content of herbage collected on Tideslow Farm during the 1973 grazing season. Grass samples from the rake show considerably raised values throughout the season and a spectacular increase in the autumn months. Samples of grass from the two fields showed raised values but these were approximately half those which had been demonstrated on the rake.

Hay samples collected in the same year showed raised values. One sample of hay used for feeding the dairy cows showed a value of 32 ppm/DM. A further sample of hay from what was considered to be a less dangerous area and which had been selected to be fed to the horses, showed a reduced value of 8 ppm/DM. Samples of straw which

Animal	Age	Date	Kidney	Liver	Bone
Lamb	Foetus	March 1973	-	77	-
	"	" "	-	202	-
Lamb	1-10 days	March 1973	193	198	-
	" "	" "	106	106	-
	" "	" "	48	63	-
Lamb	1-10 days	March 1974	-	77	-
	" "	" "	-	72	-
	" "	" "	-	241	-
	" "	" "	-	170	-
	" "	" "	-	116	-
Calf	6 month	December 1974	39	34	174
Calf	3-8 month	December 1974	34	-	386
	" "	" "	39	-	386
	" "	" "	217	-	-
Cow	Aged	December 1974	130	68	386

TABLE 7 Tissue lead concentrations found in cattle and sheep in 1973- 1974 on Tideslow farm (Values in μ mol/kg and bone concentrations are dry fat free samples. Normal tissue values < 4.8 μ mol/kg).

Identification	Blood lead (µmol/l)	
	May 5 1976	October 1 1976
1	1	-
2	1.8	1.4
3	1.9	1.8
4	1.4	0.87
5	0.87	0.87
6	1.9	-
7	1.2	1.01
8	1.4	-
9	1.4	6.3
11	1.3	0.63
12	1.2	1.1
13	1.4	1.2
14	0.87	0.6
15	1.1	0.76
16	-	0.52
17	-	1.01
18	-	1.2
19	-	1.2
20	-	1.01
21	-	1.01
Mean of all animals	**1.32**	**0.98**
Mean of repeated animals	**1.32**	**0.98**

TABLE 8 Blood lead concentrations of cattle in spring and autumn 1976

(Normal blood lead concentrations < 1.21 µmol/l Allcroft 1951).

Site and month of sampling	Lead herbage	
	Mean (µ mol/kg DM)	**Range (µ mol/kg DM)**
Great Hucklow *March* (mine site)	820	310-1690
Ladywash *March* (smelting site)	1014	425-3478
Tideslow *March* (Disturbed ground)	725	116-3,000
August	111	483-232
Control area *March*	328	205-250
August	53	24-290

TABLE 9 Lead values in pasture herbage collected from sites close to a mine, a smelting site, disturbed ground and a control area (Colbourn and Thornton 1978)

Normal pasture levels 10-40 µ mol/kg (Colbourn 1976).

were being fed to the cows and suckling calves at the time of the deaths in December 1974 showed very high levels due to trampling and contamination with soil. One sample from the feeding area in the shelter of the rake showed a value of 5,500 ppm/DM. Further straw collected from the feeding area by the road showed a value of 1,900 ppm/DM.

Discussion

The sites of the small workings were not apparent on the surface because of the levelling of hummocks by many years of cultivation. The spoil heaps had not been worked by the tributors, probably because of their low fluospar content of less than 30%. As the investigators could discount the dispersion that such tributor workings had caused elsewhere, they had to seek other reasons for the widespread contamination which was to be found distant from the rakes.

Bayliss et al (1979) found water soluble lead values of 20 ppm in the soils directly overlying the veins and values of 10 ppm as far away as 30 m. These forms of water soluble lead, zinc and copper were associated with the presence of mineral aureoles in the limestone surrounding the ore bodies. The role of ploughing and reseeding were discussed by these authors, but that played by ambulatory animals, which having ingested lead rich soil subsequently defaecate some distance away, was not considered. This may be have been due to the preoccupation of botanists and soil chemists with stationary subjects. Bayliss et al (1975) suggested a possible role played by hooves of cattle and mules in trampling and the spreading of soil.

The ingestion of soil by animals grazing grass is involuntary. Work in New Zealand and in the UK has shown that sheep may ingest as much as 30% of their dry matter intake as soil. The levels of soil ingestion by cattle in the UK have been calculated from 2.18% to 4.48% of their total dry matter intake (Thornton and Abrahams 1983). In spring, new grass shows lower levels of soil contamination because of the relatively sudden growth and consequent less chance of splashing by rain. The closer grazing of sheep results in the ingestion of greater quantities of soil. Fig 26 shows diagrammatically the possible pathways of lead in dust and the ambulatory behaviour of ruminants.

Mineralogically, the veins on this farm were predominantly of calcite with varying amounts of galena, baryte, fluorite, chalcopyrite (an important copper ore) and sphalerite (zinc blende). There were also certain secondary alteration materials of which cerussite or lead carbonate ($PbCO_3$) was the most predominant. Cerussite, from the Latin cerussa - white lead, was previously a valuable ore used as a pigment. Carbonate of lead is sweet to human taste and it was considered possible that the sweetness could have been a factor in the lamb deaths in the early 1960's.

The consequences of the discovery of such extensive lead contamination of the grazing land on this farm had considerable implications for the farmer's plans. The earlier experience of the lamb losses (Clegg and Rylands 1966) had shown the limitations where the ewes with lambs at foot could be kept. It was found that ewes and lambs had to be excluded from the rake itself and the immediately adjoining fields, until the lambs were weaned. It was considered that complete rumen function had to be established before lambs could be grazed on the rake.

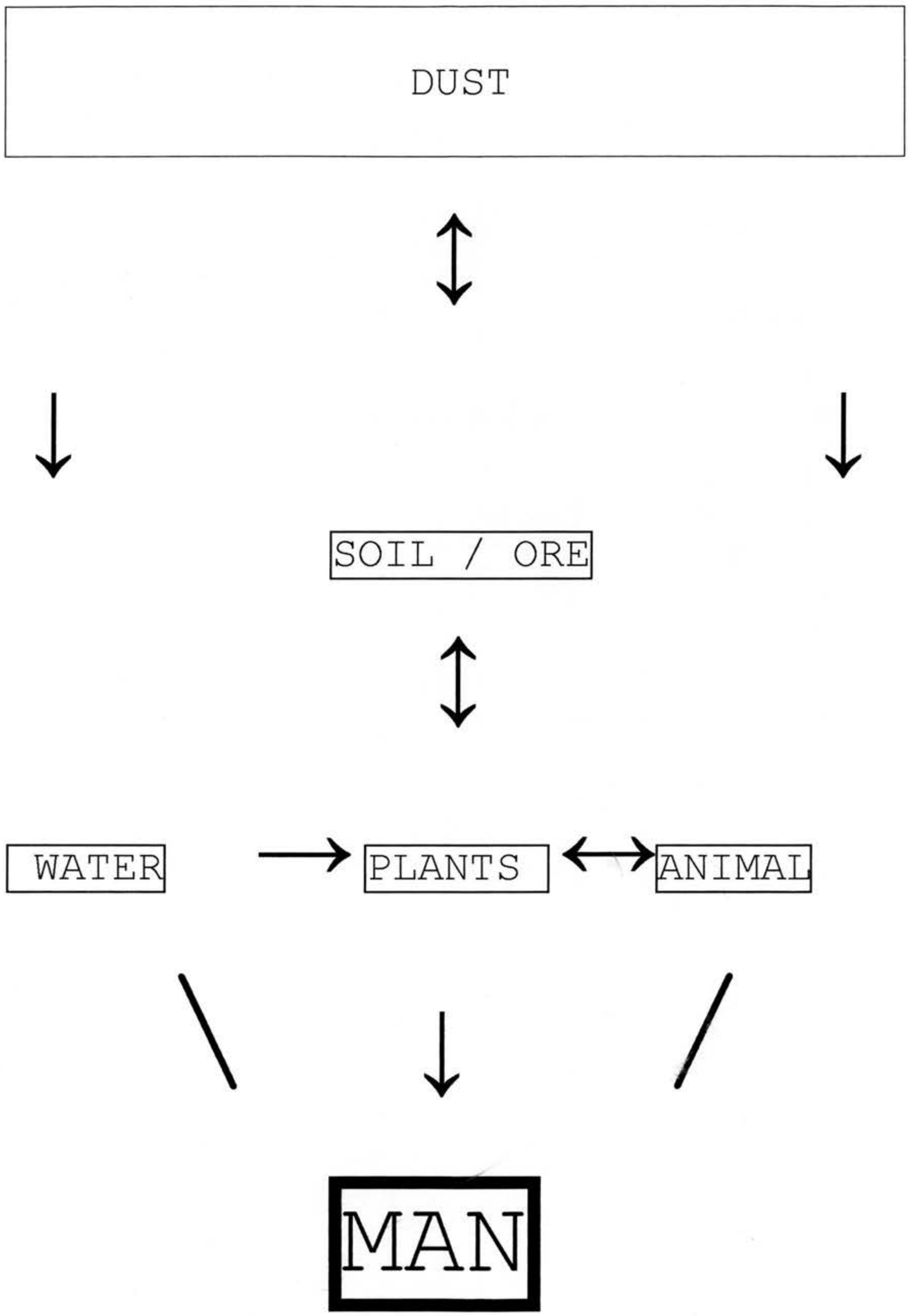

FIG 26 Diagram of the major pathways of transmission of lead to animals and man.

The cattle losses in 1974 showed that animals could not be sheltered in the rake during the winter and could not be fed there on fodder which had been scattered on the ground. The increase in the lead levels of autumn grass was now recognised as a potential risk to ewes in early pregnancy.

The farmer learned that any further disturbance of the ancient workings on the farm would be hazardous and the risks would have to be considered if tributors were to seek sources of fluospar. In 1995, the Great White Rake was declared a Site of Special Scientific Interest (SSSI) and regulations require that it is not to be subject to further alterations. Appendix H details the history and the present scientific status of this rake.

B. THE INVESTIGATION OF LEAD POISONING OF CATTLE AT THE SITE OF AN ANCIENT ORE WASHING FLOOR

One limitation of the use of large scale geochemical surveys has been that small, localised sources of lead contamination have not be found unless, by chance, a sample had been taken directly from the area. Such sources may prove to be potentially serious hazards to the keeping of livestock. The use of stream sediments in geochemical reconnaissance in demonstrating the presence of past mining, smelting and ground disturbance which have taken place upstream has been used by AGRG workers (Nichol et al 1970). It was of interest when the investigation of cases of lead poisoning of farm animals were shown to be due to historical contamination of the surrounding land and this discovery in turn was followed by a local survey.

The scale of disturbance and the effects of industry on the landscape of north Derbyshire were so considerable that it is only recently that local soil surveys have shown the extent of soil contamination. Such a survey of North East Derbyshire, covered an area which included smelting sites on Eastmoor (Wild and Eastwood 1992). It is probable that there are many further unknown sites of historical contamination.

History

The investigation led to the discovery of the site of an ancient ore washing floor on the banks of a small stream (SK 144 771). Brook Bottom is the only surface stream found in this area of the ore field and the enquiry showed the considerable use that had been made of the water supply in the past (Fig 27).

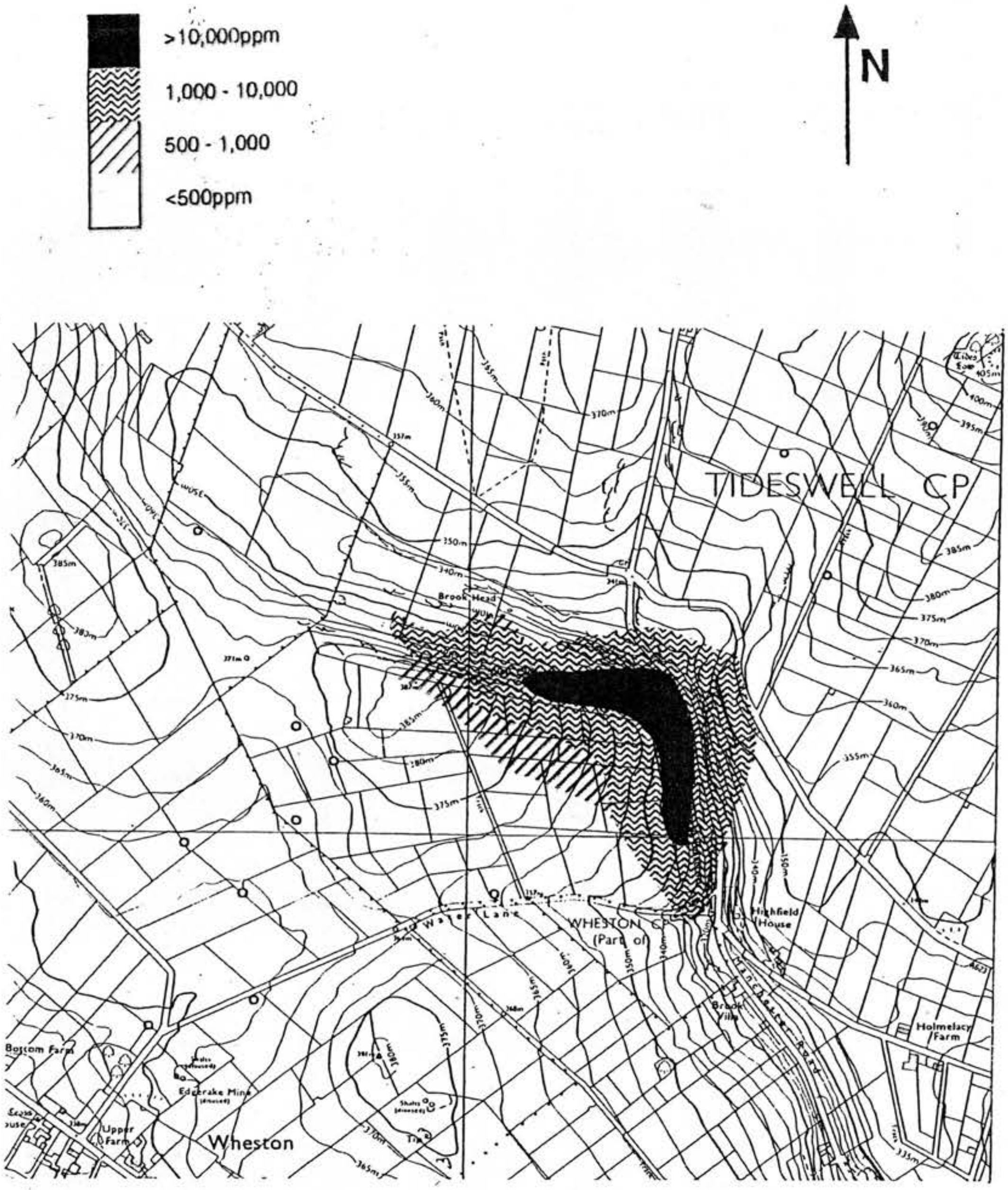

FIGURE 27 Map of the site of an ancient ore washing plant showing the lead contamination of soil. Lead anomaly in 0-15cm soils (Colbourn 1976).

Cattle were fed hay on the ground by the edges of the stream during the winter and between February and March 1973, many deaths occurred following the ingestion of lead contaminated fodder. This small valley on the limestone plateau is one of the few sheltered sites found in this bleak, wind-swept area.

Samples of topsoil and sub-soil were collected from the valley floor and sides. Stream sediment samples were collected at 100 m intervals.

Results

Extremely high lead concentrations were found in the sediment ranging from just under 4,000 to over 60,000 ppm lead (Colbourn 1976). Bank material contained similar amounts and Fig 27 shows the distribution in the valley and the position of the feeding area of the cattle. Colbourn observed that the lead/zinc ratios found here indicated that the area was also contaminated by a smelting site on the nearby Wall Cliff. Nevertheless, he concluded that the extensive contamination of the soil was due to the washing of ore. The soil was contaminated in some places to a depth of 45 cm.

Discussion

The Regional Geochemical Reconnaissance Stream Sediment Survey of the Derbyshire Area (Nichol et al 1970) does not show any stream sediment values which could be related to this massive localised contamination. Samples showing raised values of 150-700 ppm Pb were recorded from the River Wye 2 km downstream from its confluence with the Brook Bottom source. The large scale of this reconnaissance at one sample per square mile (2.59 sq km) of tributary drainage and the numerous other sources of contamination of the River Wye may be the reasons for this failure.

Ford and Rieuwerts (1968) describe the process of "buddling" or sieving of the ore in the preparation for smelting. Ore would undoubtedly have been brought down to this site from the extensive workings along the nearby Tideslow Rake.

The findings also served to warn the villagers of the dangerous levels of lead found in the locally acclaimed watercress (*Rorippa nasturtium-aquaticum*) which had been gathered from Brook Bottom from times immemorial.

C. *THE POISONING OF A DAIRY HERD BY LEAD FOLLOWING SOIL CONTAMINATION OF SILAGE*

Introduction

The introduction of new methods of farming and feeding of livestock may produce new hazards. The change from hay-making to universal dependence on silage as a winter fodder was enthusiastically accepted by north Derbyshire hill farmers. The labour saving afforded by bigger machinery powered by larger tractors helped to keep these small farms profitable and allowed the production of fodder of adequate nutritional value for dairy cows even after wet seasons.

Herd lead poisoning following the use of accidentally contaminated silage had been described. The contamination of a silage crop after a battery fell into the following harvesting machine resulted in extensive losses and required heroic surgery to remove the bits of the broken plates of the battery from the rumens of cattle (Annual Report Sutton Bonington VIC 1972).

Seven yearlings died in a group of 40 and all showed signs of poisoning. Frape and Pringle (1984) described the poisoning of a dairy herd of 115 high yielding Holstein cows in the UK. The herd was receiving a ration of high quality haylage and analysis of the haylage showed a lead value of 3,800 ppm/DM due to the presence of lead pellets which had fallen into the standing grass during clay pigeon shooting over the field.

Wardrope and Graham working from the Scottish VIC in Dumfries (1982) described poisoning of a herd of cattle by lead following contamination of silage. In this case, waste material from a lead mine had been used to construct the ramp made to feed housed cattle. The laying of a concrete surface on the ramp prevented further cases. In a further investigation, Wardrope and Graham found that mine waste had been used to repair a farm track.

History

The farm was situated in the middle of the ore field (SK 682 170) and close by Magpie Mine, a large lead mine which local tradition says had been worked for 300 years and which only ceased operation in 1924. Until recently, there were twenty open shafts close by the mine building and care had to be taken if the visitor strayed from a footpath. Fig 28 shows the position of the farm and of the fields in relation to the rakes. The established rakes and spoil heaps are shown together with the projected course of unknown ore bodies (Ineson, R - personal communication). Fig 29 and 30 show the position of the farm and the disturbed land lying to the west of the buildings. Fig 31 is an oblique aerial view which shows the topography of the area and the full extent of the rakes on this farm and on the neighbouring farmland to the south.

The herd of 64 cows had been built up over the previous three years. To obtain extra silage production required for the winter feed, extensive alterations were made to the layout of the fields. Lengths of dry stone wall had been removed and gateways had been widened to allow access for larger farm machinery. Small hillocks had been levelled off and the fields were levelled by the infilling of fissures along the lengths of the rakes.

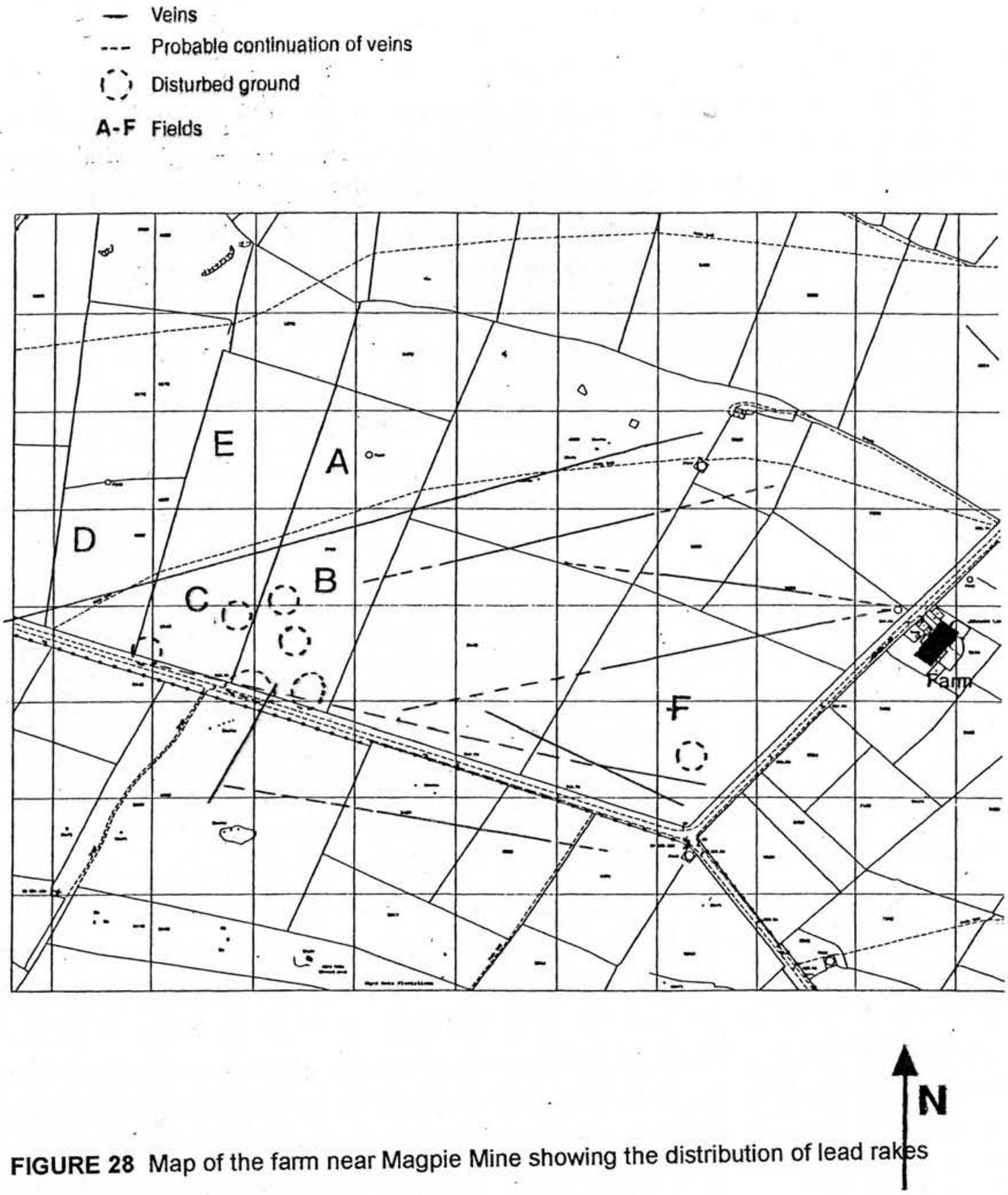

FIGURE 28 Map of the farm near Magpie Mine showing the distribution of lead rakes (1:5000) and the projected course of the veins (Ineson, R – personal communication).

FIGURE 29 Aerial view of the farm near Magpie Mine from the south showing the fields to the west and the mine to the east October 1970 (1:8600).

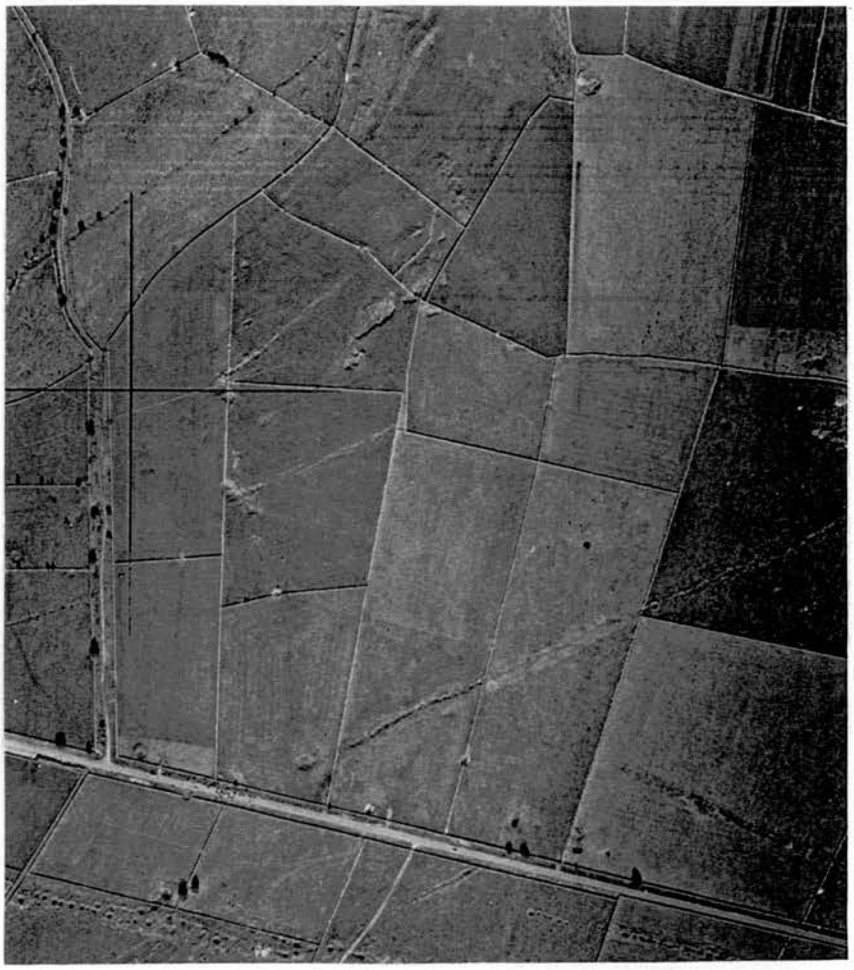

FIGURE 30 Aerial view of the farm near Magpie Mine further to the west October 1970 (1:8600). © Crown Copyright. EDA 61A.

FIGURE 31 Aerial view taken at an oblique angle from the south west showing the disturbed ground along the length of the rakes in November 1976 (1:8600).

Silage was fed ad lib from November 1978 until May of the following year. Yearling cattle were also fed silage of poorer quality. The deaths of three cows occurred during the early winter and the owner attributed these losses to hypomagnesaemia. Several of the yearling cattle had died also but the cause was unknown. Later in May, extensive illness occurred in the cows. The older cows were turned out to pasture first on May 10 and losses commenced on May 16.

Five cows died and a further cow was slaughtered *in extremis*. Twelve cows were treated successfully for lead poisoning.

Clinical examination of the animals showed that many appeared dull and several were circling and blundering into the stone walls. Trismus and grinding of the teeth were seen in ten of the cows. Later the clinical signs became more bizarre and three cows were observed walking backwards. Involuntary movements of the head and neck and rhythmic contractions of the muscles of the neck, ear, flank and tail were also noted. Fig 32 and 33 show clinically affected animals. Cow 779 died in March 1980 after showing dullness and occasional convulsions

Materials and methods

Tissue sample of kidney, liver and bone were collected for lead analysis. Blood and milk samples were taken from both the ill and nine apparently healthy cows.

The brain of a 6-year-old cow was preserved in 10% buffered formol saline for histological examination. Silage, grass and hay samples were collected for analysis in 1979 and again in 1980.

FIGURE 32 View of a cow showing signs of lead poisoning. The cow has pushed over the coping stones of the wall with its head.

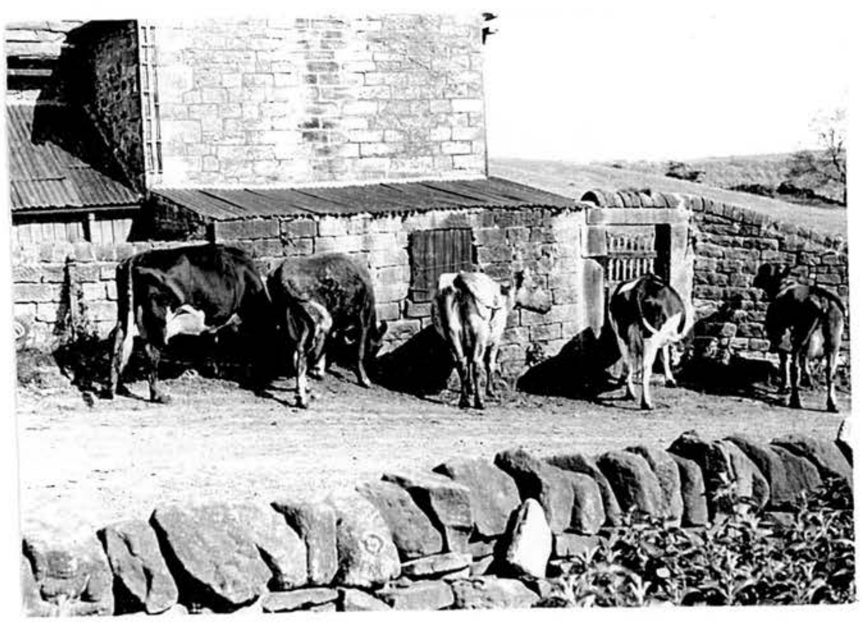

FIGURE 33 View of five cows showing signs of lead poisoning. Two of the animals are pressing their heads against the building.

Results

The results of the tissue analyses are shown in Table 10. Table 11 shows the lead values of the grass silage samples. Allcroft (1950) considered that normal blood lead concentrations of calves are below 1.21 µmol/l.

Histological examination of the brain of the cow showed moderate peri-neuronal and peri-capillary micro-cavitation of the cortex (Bradley, R - personal communication).

Silage feeding trial

Investigations on this farm continued into a second year and further samples of silage were taken in the summer of 1980. Attempts were made to find the source of contaminated samples within the 300 tonne clamp of silage but proved unsuccessful. This was because of overlapping and compression of the layers of grass that occurred as the clamp was constructed.

Blood and faeces samples were collected from the dairy cows for lead analysis on three occasions during the time the silage was fed to the cows, in late November 1980, in January and finally in late February.

These results are shown in Table 12. The initial raised faecal values in November may have been due to late grazing on lead rich pasture. Despite the death of cow Number 779, the improved situation, compared with the previous winter, was considered to be due to the dryer weather conditions at the time of silage making and also to improvements in methods of collection.

Number	Date	History	Kidney	Liver	Bone	Blood	Milk
Cow A	22/5/79	Slaughter	24.2	14.5	530	-	-
" B	23/5/79	Died	24.2	16.9	290	-	-
" C	23/5/79	Died	20	12.1	415	-	-
" D	24/5/79	Ill	-	-	-	2.9	0.2
" E	24/5/79	Ill	-	-	-	1.45	0.2
" 1-9	24/5/79	Normal	-	-	-	0.48-3.14 (1.92)	0.1-0.3
Cow 779	29/3/80	Died	-	-	-	2.17	-
Normal Values	-	-	> 0.48	> 0.48	-	< 1.21	< or =0.1

TABLE 10 Lead values found in the kidney, liver, bone (μmol/kg DM) and the blood (μmol/l) and milk (μmol/kg) of cows poisoned following the soil contamination of silage. (Bone values are based on dry, fat free samples).

Origin	Date of cutting	Lead (µmol/kg DM)
Silage fields A, B and D and E	August 1978	390
Grass field A	July 1979	960
" " B	" "	105
2 " C	" "	85
Silage field A	June 1979	250
" " B	" "	325
" " D	" "	310
Grass field A	June 1980	60
" " D	" "	100
Chlorosed grass Field A	May 1979	1990
" " " B	" "	1000

TABLE 11 The lead content of silage and grass contaminated with soil. Normal pasture levels 1O-4O µmol/kg DM (Colbourn 1976).

	November 1979	January 1980	February 1980
Blood lead (µ mol/l) and range()	0.85 (0.39-1.59)	1.1 (0.63-1.21)	0.59 (0.24-1.21)
SD	±0.33	±0.31	±0.28
Faeces lead (µ mol/kg DM) and range()	858 (240-2610)	514 (100-820)	254 (50-675)
SD	±653	±216	±230

TABLE 12 Silage feeding trial and the mean (SD±) and range of lead concentrations found in bovine blood and faeces of twelve cows. (Normal blood lead concentrations < 1.21 µmol/l. Normal faecal lead concentrations < 200 µ mol/kg DM).

The mean blood lead values found on the three successive samplings:- 0.85, 1.10 and 0.59 µmol/l were lower on each occasion than those values which had been found in the apparently healthy cows at the time of the losses. The lower lead values of 60 and 100 ppm/DM from fields A and D compared favourably with those values which were as high as 910 ppm/DM in the previous year (Table 11).

Discussion

Considerable efforts were made by the stockowner on this particular farm, to avoid running over the swathes of cut grass with the tractor wheels. A pick-up reel replaced the flail type mower used previously. Improved cleanliness on the new concrete collecting area was also thought to have been important in reducing soil contamination. The health of the herd was improved when compared with the previous winter and the milk yield increased.

The scale of the losses on this farm caused considerable local concern amongst other dairy farmers making silage on the limestone plateau. The trials and demonstration of improved silage making were of interest to many and claim can be made that many dairy farmers subsequently improved their harvesting methods.

D. *THE POISONING OF A DAIRY HERD BY LEAD FOLLOWING THE INDUSTRIAL CONTAMINATION OF SILAGE*

Introduction

Lead is the most common cause of the accidental poisoning of domestic animals in the UK (Lloyd 1983) and in north America (Waldron and Stofen 1974). Cattle have been poisoned by the ingestion of the most diverse items, from lead-based paints (Woods 1965), used or discarded oil and oil filters (Hammond et al 1956; Buck 1970) and even sailcloth from windmills painted with white lead (Edwards 1924). Frape and Pringle (1984) described the poisoning of a dairy herd as the result of a lead tractor battery falling into the forage harvester. Todd (1962) carried out an early survey of cattle deaths due to lead poisoning in northern Ireland.

Cases of lead poisoning in grazing animals resulting from industrial causes have been numerous and have frequently occurred in the proximity of smelters (Djuric et al 1971; Bolter et al 1973; Hammond and Aronson 1964; Lagerwerff et al 1973; Little and Martin 1972). Kradel et al (1965) described the contamination of cattle fodder which occurred in the vicinity of a battery burning plant.

Sutton Bonington VIC investigated numerous cases of industrial lead poisoning usually affecting one or more individuals in a group of young cattle. Lead poisoning of several cows within a herd was investigated in one case where 15/25 died. The poisoned cows had sought out and ingested ash from the site of a bonfire made from an old railway carriage (Annual Report Sutton Bonington VIC 1960). The poisoning of a whole herd following the involuntary consumption of contaminated fodder as the result of soil contamination has been described earlier. The present case describes the aerial contamination of silage lead caused by an industrial process.

History

This case describes the involuntary uptake of lead by all the 90 cows in one commercial dairy herd. Silage was fed to the herd for the first time on this farm during the winter of 1978 and the cows consumed between 8-11 kg per head daily. The silage fields lay to the north and west of a plant used to grind the discarded cases of car and commercial vehicle lead-acid batteries containing 0.5% lead. Fig 34 shows the plant and the scale of the operation. The ground

material was destined to be used as fuel in a power station generating electricity. Fig 35 is a map of the farm showing the grass fields which lay on higher land to the north of the plant situated at the bottom of a small valley.

The grinding of batteries continued throughout 1978 and at some time during the summer, an extensive fire occurred in a large heap of battery cases. The heap measured some 6 m in height and 600 m in length and the copious smoke from the fire drifted onto the sloping fields due to the prevailing wind from the south.

Silage feeding commenced on 16 October and the first clinical sign was seen three weeks later. A cow was reported to be blundering into objects on the way to the milking parlour and direct ophthalmoscopic examination showed bilateral swollen pale optic discs. Ten days later the herd appeared dull and the milk yield was reduced. On 12 December, four cows died within two days and 12 others showing signs were treated successfully for lead poisoning.

FIGURE 34 View of an industrial battery crushing plant and a pile of battery casings.

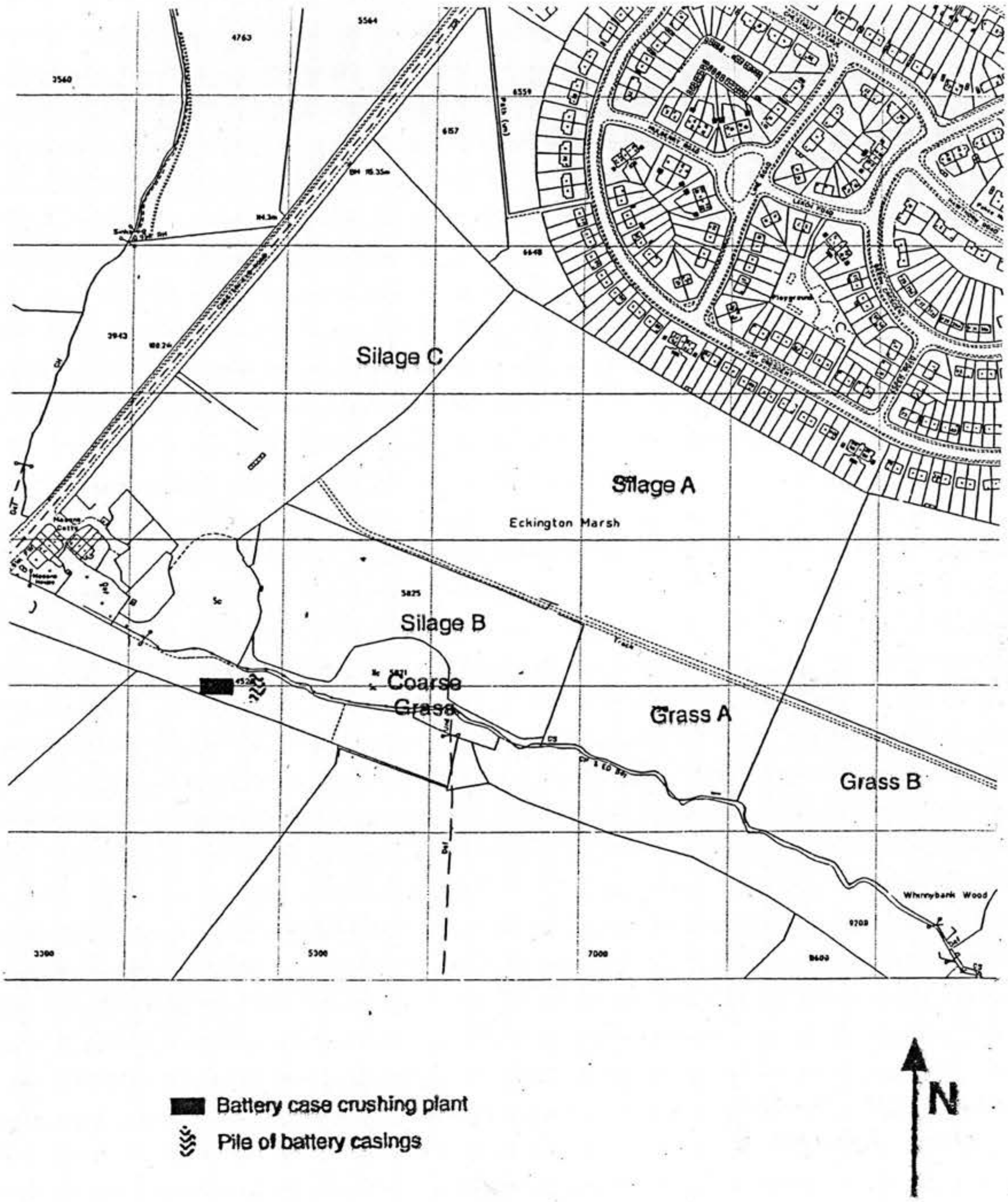

FIGURE 35 Map of the contaminated farm and the location of the battery crushing plant (1:5000).

Materials

Blood and milk samples were taken from 18 cows ten days after the first death and bulk samples were taken of both the morning and evening milking. The eyes and sections of the kidneys of two cows which died were preserved in 10% buffered formol saline.Core samples were taken from the silage clamp and attempts were made to locate the samples at the depths which were considered to be from fields A and B.

Samples of the coarse grass growing in the hedgerow by the plant was also collected. As there was uncertainty about the date that the grinding plant finally ceased to operate, repeated silage and grass samples were collected from fields A and B and also from a further grass field C.

Results

The results of the analyses for lead of tissues and the milk samples are shown in Table 13. The results of the analyses of the silage and grass are shown in Table 14. Values as high as 1940 µmol/kg were found in the coarse grass which had been exposed to contamination throughout the summer and autumn. Silage samples from the clamp which represented grass cut in June 1978 showed raised values as high as 970 µmol/kg lead. Despite the continued operation of the plant for some time during the 1979 season of grass growth, the lead values from the same fields were lower.

Histological examination of the eyes showed oedema of the optic discs with congestion of retinal vessels. Macrophages and hyalocytes were present in the adjacent vitreous body of each eye. Kidney sections stained by the modified Ziehl Neelsen method of Wachstein (1949) showed the presence of small acid-fast intranuclear inclusion bodies in the cells of the proximal convoluted tubules.

Identity	**Date**	**History**	**Kidney**	**Liver**	**Blood (mean)**	**Milk**
Cow A	3/12/78	Died	43.5	48.3	-	-
Cow B	21/12/78	"	48.5	24.2	4.7	-
5 Cows (C-G)	14/12/78	Blind	-	-	2.7-5.8 (4.4)	-
18 Cows (1-18)	23/12/78	Normal	-	-	0.8-2.3 (1.46)	0.3-1.7
Bulk milk *am* *pm*	24/12/78 "	-	-	-	-	0.7 0.9
Normal	-	-	<10	<10	<1.21	<or=0.1

TABLE 13 Lead concentrations found in the kidney and liver (μmol/kg DM) and the blood (μmol/l) and milk (μmol/kg) of cows poisoned by fume contamination of fodder.

Origin	Date of cutting	Lead (μmol/kg DM)
Silage field A	June 1978	485
" " B	June 1978	970
Coarse grass	December 1978	1940
Silage field A	July 1979	75
Silage field B	July 1979	240
Silage field C	July 1979	20
Coarse grass	July 1979	970
Field D south of plant	June 1978	15
Field E " " "	June 1978	40

TABLE 14 The lead content of silage and grass in the vicinity of a battery grinding plant. Normal values 10-40 μmol/kg DM (Colbourn 1976).

There was a lack of udder development shown by those cows calving during the remaining winter. These cows did not show the expected early peak in the lactation curve although they maintained a consistent yield later. A cow with an anticipated yield of 1,000 l produced only 600 l during its lactation.

Discussion

The daily intake of lead following the consumption of 10 kg of silage with a lead content of between 500 to 1,000 ppm would be from 5 to 10 g daily. It is considered that most of the cows in this herd would have consumed between 5 and 10 g daily for some of the time before the silage was withdrawn. Verhoeff et al (1981) investigated the poisoning of cattle by lead contaminated roughage from motorway verges and considered that the minimum toxic dose for adult cattle was 250 mg of lead when fed over a long period.

The significance of the lead values found in the milk samples is discussed in the subsequent section on Public Health Measures.
The farmer was awarded the sum of £8,000 in an out-of -court settlement. This was based on the loss of milk yield, the cost of veterinary treatment, the purchase of additional silage and the cost of the disposal of the contaminated silage by ploughing the material into arable land. In the management of the poisoning of a dairy herd, early decisions had to be made whether it was necessary to secure a source of uncontaminated feedstuff. The sampling of a massive silage pit containing a crop weighing several hundred tonnes proved difficult and the results were unreliable. The lack of certainty was because of difficulty of determining the position of layers of grass from a particular field. The continued monitoring of blood lead concentrations is now required by legislation and could -continue for as long as three months (Preece 1995a).

E. *PASTURE LEAD LEVELS IN THE UNITED KINGDOM AND THE UPTAKE BY GRAZING ANIMALS*

For many years, cases of lead poisoning continued to be reported to the Sutton Bonington VIC from the sites of ancient mining and smelting sites and often occurred when animals strayed on to mine spoil heaps. The lead rakes were also grazed intentionally by stock owners and a calculated risk was taken.

Table 15 lists the references to raised lead levels found in pastures in seven areas of the UK. Eleven of the references describe lead poisoning of grazing in local livestock. Shearer et al (1940) reported that the lead content of grass collected from four fields in Derbyshire in January, showed a large increase over the grass collected from the same fields in November. They considered that the results were too scanty to draw conclusions about the significance of their findings.

In 1978,it was decided to extend enquiries and to measure the uptake of lead by cattle on farms where the soil and herbage lead values were already established. Thornton et al (1988) selected farms to investigate the degree to which blood and faeces lead values would reflect the amounts of lead in the soil. Several of the farms were known by the VIO from previous investigations as were the circumstances under which stock losses had occurred. Blood samples were taken from fifteen cattle from each of twelve farms. Grass samples were collected from nine of these farms (A to I) in 1979 and again in 1980 for lead analysis. Titanium estimations were carried out on all the samples to determine the degree of soil contamination of the silage (Tasker, C - personal communication). Hayes (1978) had

Location	Herbage range (mean)	Enquiry	Authors
Derbyshire	41-258 (158)	"Swayback"	Innes and Shearer (1940)
	37-350 (96)	"	" "
N Pennines	427 (914)	Lamb poverty	Stewart & Allcroft (1940)
Leadhills	162-764 (278)	Lamb osteoporosis	Butler et al (1957)
Derbyshire	60-290 (100)	Lamb osteoporosis	Clegg and Rylands (1966)
Scotland (Aberdeenshire)			
Spring	0.3-1.5	Survey	Mitchell and Reith (1966)
Autumn	30-40		
Ireland	(up to 2000)	Mining	Donovan et al (1969)
Swaledale	350	Calf deaths	Harbourne et al (1968)
Ireland	(up to 1875)	Horse deaths	Egan and O'Cuill (1970)
S Wales	30-100	Geology	Alloway and Davies (1971)
S Wales	6-105	Pollution	Goodman and Roberts (1971)
Derbyshire			
Spring	24-600 (150)	Pollution	Colbourn and Thornton (1978)
Autumn	10-48 (23)	"	" "
Derbyshire	60-300 (156)	"Swayback"	Alloway (1973)
Derbyshire	390-1990 (500)	Cattle deaths	Clegg unpublished (1978)
Derbyshire	75-380 (240)	Pollution	Clegg unpublished (1979)

TABLE 15 List of grass and silage lead values found in the British Isles.

(lead values in mg/kg DM).

previously reported that the use of flail mowers and harvesters resulted in higher soil contamination of silage. These observations were made in the neighbouring county of Staffordshire where high rainfall caused the same problems of soil uptake.

Results

The farmers had previously been advised on the methods to reduce soil contamination of the silage crop during the collection and the making of the clamp. Observations were made of the height of the cut of the grass on each occasion. On Farm A observations were made in 1980 on the differences between cuts of 25, 50 and 76 mm (1, 2 and 3") height and are shown in Table 16.

The farmers were advised that the use of pick-up reels would reduce the soil and dust contamination that was a feature of the collection of grass by the more commonly used flail type harvesters. Farmers were also advised to use a concrete platform for the tipping area by the clamp. Some were prevailed upon to use a roller to flatten molehills before the grass had commenced to grow. Table 16 shows the results of the lead estimations of the soil and grass and of the titanium estimations of the silage. On farm A, a stubble height of less than 25 mm was found to increase soil contamination and later a cutting height of 60 - 75 mm was recommended. The titanium values show that high levels of contamination occurred on farm G in the second year. Very high lead soil values were found and were associated with a working fluospar mine on the adjoining property.

Discussion

An important report with considerable implications for farming in Derbyshire was published in 1994 (HMSO 1994) describing an 18 month

Farm	Method of harvest	Soil Pb	Grass		Silage (1980)		Silage (1979)	
			Pb	Ti	Pb	Ti	Pb	Ti
A	Direct cut 3 in Plot mown 1 in Direct cut 3 in Mown 2 in Direct cut 3 in Mown 3 in	586 873 313 299 197 294	6 21 3 6 6 6	5 48 3 14 9 4	149 207 101 89 40 32	160 280 190 150 230 120	52	60
B	Standing grass Swath grass	108	2 5	4 5	9	31	21	50
C	Standing grass Swath grass	256	5 4	7 2	17	54	42 69	40 570
D	Standing grass Swath grass	830	5 4	11 77	33	82	54	50
E	Standing grass Swath grass	634	4 6	9 15	19	40	28	55
F	Standing grass Swath grass	183	4.1 2.9	11 3	17	62	21	130
G	Swath grass	1934 576 6536	23 48 15	6 20 3	89	81	269 313 350	130 160 310
H	Swath grass	342	6	4	89	150	8	75
I	Swath grass	1790	15	5	20	92	70	230

TABLE 16 Herbage lead values found in the field trials of 1979, 1978. The titanium values indicate the scale of lead contamination.

research programme commissioned by the Department of the Environment (DoE). It was entitled "The Reclamation and Management of Metalliferous Mining Sites". The guidance given was to enable the selection of suitable after uses for these sites and to identify feasible methods for their management and restoration while preventing pollution. A DoE Derelict Land Survey of 1988 had estimated the area of land affected by metalliferous spoil in England to be some 4,800 ha of which 1,300 ha "justifies reclamation" over substantial tracts of Derbyshire, Cornwall and the North Pennines.

Guidance on the assessment of contaminated land is given by the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL). The ICRCL has published a series of guidance notes on dealing with different types of contaminated land. Guidance Note ICRCL 59/83 " Guidance on the assessment and redevelopment of land " (HMSO 1987) covers the planning aspects of contaminated land, types of contaminants and public hazards, identification of contaminated land on the basis of past site use, site investigation and assessment. Trigger concentrations of contaminants may be considered to be threshold, below which a site may be considered to be uncontaminated - or to be trigger action concentrations, above which some form of remedial action is essential. The concentrations between these levels are considered to be within a "grey area" and judgement is then made according to the use of the site. ICRCL 59/83 states that the threshold trigger values for the heavy metals for domestic garden/allotments to be 5,000 ppm/DM and 2,000 ppm/DM for public parks and open spaces.

Guidance Note 70/90 " Notes on the restoration of and aftercare of metalliferous mining sites for pasture and grazing " (HMSO 1990) gives trigger values for grazing stock as 1,000 mg/kg air dry weight. An accompanying note states that recommendation is "For calves, sheep and horses -assuming that plant uptake is normal, the stock are continuously exposed to these concentrations and that if it is proposed to manage the sward in such a way that only a relatively low level of soil contamination of herbage will occur. In such cases, the soil may comprise up to 5% of the dry matter uptake. Under less favourable conditions soil ingestion may be much higher".

Classification is made of the Great White Rake (Tideslow/High Rake) in report (HMSO 1994). The history of the rake is described (Appendix H) and its present archaeological and botanical features. It is suggested that the site may benefit from occasional disturbance to maintain a colonising metallophytic flora. This is a very different priority from the one held by a distraught young farmer who was losing lambs, in the early days of the investigations described in this thesis.

Thornton et al (unpublished data) found that the cattle blood lead concentrations reflected those of the soil values. Over 28% of the individual blood lead values of animals from the heavily contaminated farms showed concentrations above the 10 µg/100 ml found as the mean values found on the uncontaminated farms in the summer.

This retrospective project was undertaken to establish lead levels in pastures on the farms which were already known to suffer losses from lead poisoning and was an attempt to establish how widespread these problems were and what remedial measures could be taken. It was quickly realised that contamination with lead was widespread and in some areas this was severe. It also became obvious that the height of cut and the contamination of silage with soil had an effect on the lead status of the herd.

F. *PUBLIC HEALTH MEASURES*

A comparison of the milk lead concentrations of the two herds fed silage which are described in this chapter - the herd in which the silage was contaminated with soil - and the second herd, poisoned by aerial pollution of grass, showed higher values for individual cows in the second herd (0.3 - 1.6 µmol/kg) than those found in the first herd (0.1 - 0.3 µmol/kg)(Table 17 and 18). The second herd suffered a more acute poisoning with a known length of exposure of three weeks and the daily lead dosage and total intake over the period of exposure were known.

In contrast, the first herd suffered chronic lead poisoning for six months as a result of being fed soil-contaminated silage. It is probable that this extra burden of lead affected animals which had already been exposed to raised lead levels from grazing and from fodder during their earlier lives on this farm.

The raised milk lead concentrations were reported to the medical authorities as in each case the herds were supplying whole milk for human consumption. In both cases the Community Health Physician considered that the milk from the surviving cows was fit for human consumption. However, in the case of the herd suffering from the more acute poisoning from industrial contamination, concern was expressed by one authority, that milk with these raised

Identity	Blood (µmol/l)	Milk (µmol/kg)
Cows 1 - 9	0.48 - 3.14	0.1 - 0.3
Mean [SD]	1.92 [±0.85]	0.21 [± 0.06]
Normal	< 1.21	< or = 0.1

TABLE 17 The blood and milk lead concentrations found in cows from a herd poisoned by soil contaminated silage.

Identity	Blood (µmol/l)	Milk (µmol/kg)
Cows 1 - 18	0.8 - 2.3	0.3 - 1.7
Mean [SD}	1.46 [± 0.53]	0.75 [± 0.37]
Normal	< 1.21	< or = 0.1

TABLE 18 The blood and milk lead concentrations found in cows in the herd poisoned by fume contamination of silage.

concentrations should not be fed to infants for long periods without dilution (Barltrop, D - personal communication). It was not realised until a week later that an infant belonging to the farmer's family had in fact been fed milk from the herd as the mother had suddenly ceased to lactate. Blood lead concentrations were rapidly determined for the baby and for the other members of the family. The blood concentrations found (<40 µg/ml Pb) did not indicate a need for treatment. An alternative milk supply had been sought for the infant.

Concentrations of lead in cow's milk in the UK at that time were usually found to be less than or equal to 0.1 µmol/kg (0.02 mg/kg) (MAFF 1982). Pinkerton et al (1973) found the median bovine milk lead value to be 0.02 µmol/kg. This value was four times as great as that found for human milk. The range was also greater, with values between 0.04 and 0.73 µmol/kg Pb for individual cows. The lead intake of infants up to 7 months showed values of 1641 µg/l for the breast fed and 6710 µg/l for the bottle-fed baby. It was estimated that a bottle-fed infant given a diet of cow's milk plus high solids, could ingest thirty times the lead content of a baby fed exclusively on breast milk and that milk, either human or bovine, contributes about one quarter to one half of the total human dietary intake of lead in the first year of life.

The Survey of the Lead in Food of the Total Diet (MAFF 1982) reported that there were significantly higher lead concentrations in the milk supply sampled in Sheffield. This sampling was part of a national monitoring scheme in the UK and it is considered that these higher concentrations reflect the dairy's major source of milk from the dairy herds maintained in the ore field. A conclusion of the report was that nevertheless, this level of 0.097 µmol/kg Pb remained very low.

More recently, concern has been expressed about raised heavy metal residues found in game. Langgemach et al (1995) found only low values in animals grazing land near Berlin treated with human sewage but lead tissue concentrations were greater in rabbits than those found in roe deer. However, Wolkers et al (1994) found that the tissue lead values of red deer and wild boar shot in the Netherlands were higher than those of domesticated animals. Both the high cadmium concentrations and the knowledge that organs of these animals were taken from one highly contaminated area, it was considered they would be unsuitable for human consumption.

Tissue lead values found as a result of the experimental poisoning of cattle for five months did not exceed 1 mg/kg (4.83 µmol/kg) and at the time of the publication it was stated that there was no hazard to humans from the meat of animals exposed to toxic levels of the metal (Allcroft 1950; Allcroft and Blaxter 1950). The authors recorded that liver and kidney values were higher than meat concentrations but did not rise above 2 mg/kg (9.66 µmol/kg) and concluded that these organs were not a hazard to humans when considered as part of the total dietary intake.

The procedures that are to be taken following the diagnosis of lead poisoning in food animals were considerably revised in 1989. This followed the extensive lead poisoning of cattle on 2,000 farms throughout the UK due to contamination of a shipload of imported feedstuff (SVS Annual Report 1989). The VIS was involved in advising the stockowners and in monitoring those owners where there was a risk that animal products from poisoned animals could enter the human food chain.

The role of the VIS is to establish a diagnosis of poisoning with all speed, to collect information and to secure the safety of the food chain on behalf of the Emergencies and Food Protection Division (EFPD) of MAFF. The majority of farm animal poisoning incidents in the UK involved the local VIC. The veterinary practitioner may have been called to a case and found evidence of poisoning. This person would then submit specimens of blood or viscera to a VIC for lead analysis. Otherwise, the practitioner may have submitted material for *post-mortem* examination and a diagnosis of lead poisoning could have followed. In all cases of unexplained deaths in calves, VIC's investigated the possibility of lead poisoning by carrying out a lead analysis on kidney cortex. At Sutton Bonington VIC, lead kidney analyses were required in cases of unexplained death in cattle of any age and suspected cases of poisoning of dairy herds were visited by the VIO within twenty four hours.

In the procedures which are contingent to a diagnosis of lead poisoning in a food animal, the VIS takes the key role in the investigation and the ensuing communications. The instrument used is the Food and Environment Protection Act 1985, whether the source of contamination is chemical, biological or radioactive. Ministers have wide powers to restrict stock movements and also to direct persons, whether or not they are affected by the order, to do anything which is considered necessary or expedient to prevent the consumption by humans of contaminated food. The bodies which are to be notified and consulted concerning the subsequent procedures, depend on the circumstances.

The EFPD co-ordinates the action of government whilst the Regional Director (RD) of the MAFF Region is responsible for major emergencies within his region. The Food Science Division (FScD) of MAFF provides advice on the risk to the human food chain and in serious cases this division consults the Department of Health. Chemical safety of Feed Division (CSFD) of MAFF provides advice if animal feedstuffs are found to be contaminated. The Veterinary Medicines Directive (VMD) is involved in cases where either medicines or feed additives are suspected as a cause of poisoning.

When poisoning of a food animal has been established, and the poison identified, the VIO is required to seek the owner's agreement to restrictions on the movement of all the animals which might possibly have been affected by the poison. This restriction lasts for 14 days to allow time for confidential enquiries to be made about the scale of the poisoning - and to ascertain whether meat or other animal products, including eggs, might enter the human food chain. Of three hundred cases dealt with between 1991 and 1994, in only one case, of the lead poisoning of ducks, was it necessary to seek an Order under the Food and Protection Act 1985, to require the owner to stop selling contaminated eggs for human consumption (Preece 1995a).

In the case of lead poisoning, the owner is asked to agree to a longer period of voluntary restriction on the movement of the affected group of animals. If the period proves to be longer than two weeks, there will be at least one visit by an Animal Health Officer who is required to ascertain that the owner has complied with the conditions. The persistence of lead, which had accumulated in tissues of cattle poisoned during the extensive outbreaks of 1989, was found to be as long as three months. When lead poisoning is established, a three month period of voluntary movement restriction from the outset is sought.

In the case of lead poisoning, it is possible to remove animals from such restriction for slaughter or for sale. The owner at his/her own expense must be able to demonstrate that the animal's blood lead concentration is below 1.21 μ mol/l, that is within the statutory limits defined by the Lead in Food Regulations 1979 (Preece 1995).

The interpretation of blood lead values suffers from two disadvantages. The blood level does not always correlate with the lead concentrations present in other tissues of the animal and secondly, individuals in the same group may show differing clinical signs, although possessing similar blood lead values.

MAFF publishes Welfare Codes for each of the farm animal species. The codes are made under the provisions of the Agriculture (Miscellaneous Provisions) Act 1968, in order to encourage stock-keepers to adopt the highest standards of husbandry. The codes are issued with the recommendation that they should be available to all members of staff and that they should be read and then acted on. The Code for cattle (MAFF 1991) describes the risks of lead poisoning from old paint work and whenever second-hand materials are used in livestock buildings.

The leading role taken by the VIS in enquiries into the chemical contamination of human food has proved effective. The close working relationship of the practitioner with the farming community has also helped to impress on stockowners the importance of the correct disposal of containers which had contained poisons and obtaining the correct feed for the type of stock kept.

In the past, safety levels of poisons for humans have been assessed in a different way from those which were considered dangerous to farm animals. The life span of the animals which are the principal sources of meat and include pigs, poultry, lamb and veal, are all comparatively short. Beef cattle have a longer span but these animals are more commonly housed and so may exist with less risk of exposure to noxious chemicals in the environment. Horses may live long enough to be compared with man for their long life span. The accumulation of cadmium in the kidney of elderly horses is of interest as they may have spent a large part of their lives at pasture exposed to environmental risks (Lloyd 1983).

In the case of lead poisoning, experimental feeding of cattle with lead compounds for five months was shown to cause clinical signs and death. Nevertheless, tissue concentrations were found not to exceed 1 mg/kg and at that time it was stated that there was no hazard to humans from the meat of animals exposed to toxic concentrations of lead (Allcroft 1950; Allcroft and Blaxter 1950). These authors recorded that liver and kidney concentrations were higher but did not rise above 2 mg/kg Pb. The authors concluded that lead from these organs was not a hazard in the total dietary intake of the metal.

The safe intake of toxic metals by grazing animals has in the past been considered principally because of mortality and reduced productivity of the survivors. A new awareness of the significance of heavy metal tissue residues and of dangerous organic environmental contaminants, has resulted in the setting up of sampling and monitoring procedures for particular residues.

G. *LEAD POISONING OF SWANS AND OTHER SPECIES OF ANIMALS*

In the wild, water birds are poisoned by the vast quantities of lead scattered in their habitats. In the USA, it has been estimated that each year 6,000 tons of lead are deposited from shot-guns (Andrews and Longcore 1969). Estimates of the number of birds which die in the USA vary; authorities quote high figures and as many as one million a year has been postulated (Munro and Solman 1967; Bagley et al 1967; Richter and Schlatter 1971). Poisoning of geese by lead from shot ingested in the vicinity of clay-pigeon shooting sites was described by Shore et al (1984). In the UK, the Nature Conservancy Council Report (1981) on lead poisoning of swans (*Cygnus olor*) described the history of the mortality due to all causes and particularly the poisoning that resulted from the ingestion of lead shot.

The initial observations of Simpson et al (1979) of Sutton Bonington VIC, on birds from the river Trent, were followed by the submission to the laboratory of birds from the river Avon and then later from the Thames and other waterways in the UK. Table 19 shows the number of submissions of swan viscera and carcasses to Sutton Bonington VIC from the Trent, Avon and from other sites in the UK. The percentage of deaths from lead poisoning of birds received from the Trent was 100 % in some years. Mortality was found to be particularly high in the case of swans from flocks of non-breeding birds.

Year	River Trent	River Avon	Other sites	Total	% due to lead
1973	17/17	0/0	1/12	18/29	62%
1974	5/6	2/2	10/21	17/29	58%
1975	9/9	17/19	7/12	33/40	82%
1976	13/14	13/14	8/22	34/50	68%
1977	6/7	6/13	6/56	18/76	24%
1978	23/24	4/4	3/9	30/39	37%
1979	18/20	1/4	5/6	24/30	80%
1980	8/8	6/7	28/29	42/44	95%
1981	4/10	9/13	16/85	29/108	27%
1982	4/16	5/16	28/69	37/101	36%

TABLE 19 Showing the number of submissions and the number of deaths of mute swans *(Cygnus olor)* due to lead poisoning from the Trent, Avon and other sites (1973-1982).

The signs shown by mute swans (*Cygnus olor*) suffering from chronic lead poisoning are those of a paralysis of the gizzard and the failure of the grinding action of this organ. Impaction of the gizzard follows with a progressive loss of condition until a bird may weigh only 35% of its original weight. There is an abnormal carriage of the head as the lower neck is supported by the back. Later the bird may lie with the full length of its neck show the characteristic carriage of the neck of a lead poisoned swan. Fig 37 shows an assortment of lead weights used in fresh water fishing that were removed from the gizzards of lead poisoned swans.

The Trent had been described as a "biological sink" where juvenile and non-paired adults congregated, became poisoned and died. The fluctuations in the population had not been understood as birds would die within a few months of arrival and were then replaced by young, solitary birds.

The recommendations of the Nature Conservancy Council Working Group on Lead Poisoning of Swans (NCC Report 1981) were acted upon and the use of lead shot by anglers was restricted. The report recommended the phasing out of the use of split-shot lead by anglers within five years and that publicity should be given to the dangers to swans of discarded lead. Regulations were made which required the substitution of lead by tin and tungsten in the weights used by fresh water anglers.

Analyses were carried out in subsequent years by Sutton Bonington to monitor the decline in the number of lead poisonings and the resulting continuous improvement in the health of swans on all the waterways of the UK. Birkhead et al(1982) reported on the lead status of swans on the Thames. Macdonald et al (1990) studied the

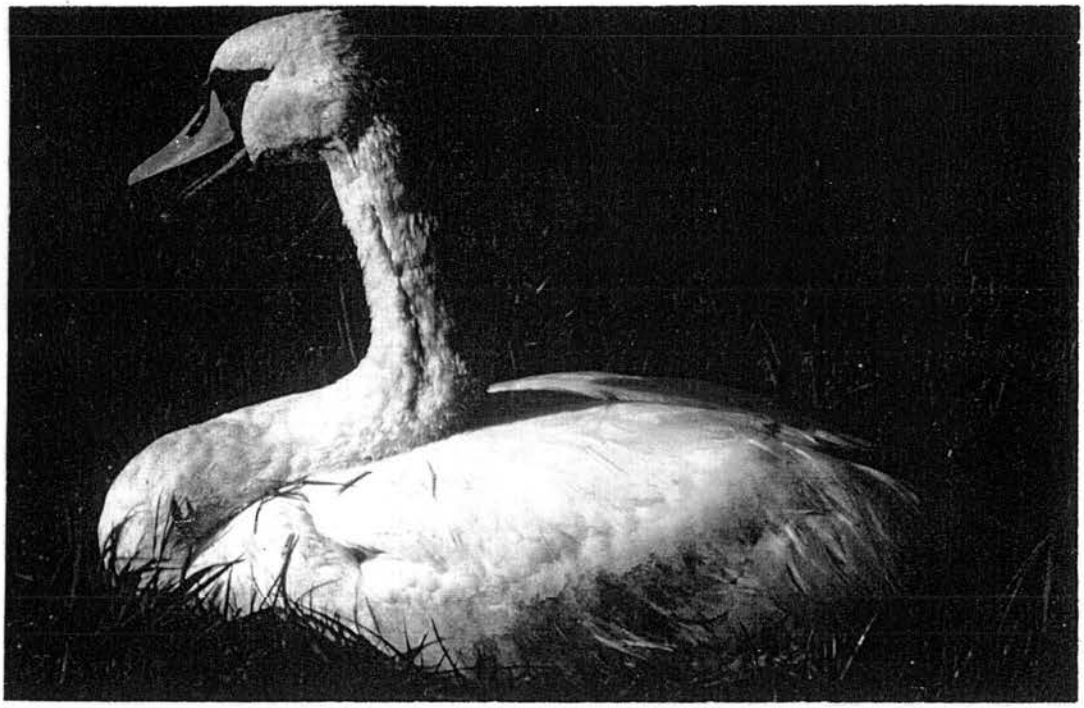

Fig 36 Mute Swan (*Cygnus olor*) showing signs of lead poisoning.

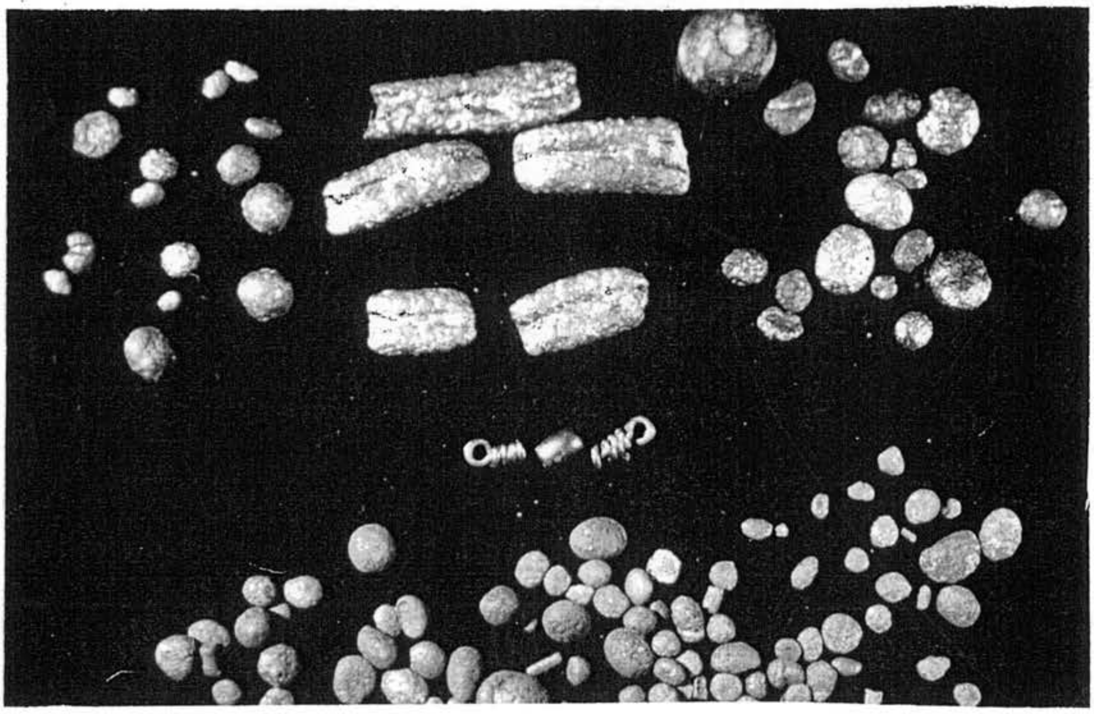

Fig 37 Various lead weights used by anglers and removed from the gizzards of Mute Swans (*Cygnus olor*).

mortality of swans in Scotland and the few cases of lead poisoning that were found. Macdonald found that in Scotland, lead poisoning of swans was principally due to the ingestion of shot-gun pellets.

The welcome given to the return of large numbers of swan to rivers in the UK, did not meet with universal approval however. A correspondent of the newspaper 'The Times' (May 22 1995) reported that swans were stripping rivers of weeds especially water crowfoot (*Ranunculus aquatilis*), which sheltered fish and that the birds were also feeding on spring pasture and fouling and trampling crops.

The poisoning of dogs by lead has been described only infrequently in the UK (Wilson and Lewis 1963) but frequently in north America (Mitchell 1940; Pettit et al 1956; Zook et al 1969; Zook et al 1970; Priester and Hayes 1974; Kowalczyk 1976). Zook et al (1969) considered that puppies were more at risk than adult dogs because of their habit of chewing.

However, it was in New Zealand that the public health significance of lead poisoning of dogs was first recognised (McLeavey 1979). Lead poisoning had been described there as early as 1955 and Staples (1955) established the criteria for diagnosis. Dodds and Staples (1956) described many cases in the field.

McLeavey (1977) reported cases in one veterinary practice in older part of the town of Christchurch and it was thought that these cases were occurring in the households of families in lower socio-economic groups living in run-down accommodation. Flaking paint, lead pipes, linoleum, batteries and putty were considered to be sources of lead for both small children and dogs.

The Department of Health of New Zealand required that all cases of lead poisoning in animals should be reported because of possible risks to young children living in the same surroundings.

Zoo animals were at risk from lead poisoning often in the past from painted cages (Fischer 1954; Sauer et al 1970 and Zook 1970 and 1972). One zoo outbreak was attributed to environmental pollution, when samples of grass collected from nearby showed the high value of 3,900 ppm of lead (Bazell 1971).

Discussion

The incidents described in this section on lead poisoning were all investigated by the Sutton Bonington VIC in the 25 years between 1960 and 1985. This is partly because the author was active in the field during this period but also because changing circumstances in agriculture and the gaining of minerals, brought the problems to prominence at this time.

The earliest lead workings go back over many hundreds of years. It was known early in the 18 th century that lead was toxic but the scale of morbidity and mortality was accepted. The regulatory authorities had little effect on the control of pollution, no scientific means of assessing the severity and extent of the problem and perhaps no real will to do anything that would interfere with profitable enterprises often financed by local Sheffield businessmen. This attitude prevailed until recent times. The heyday of Derbyshire lead mining was the middle of the 19 th century and then declined and so spoil heaps were left alone and became overgrown. Lead toxicity problems persisted, but in a low input low production agricultural system, it was regarded more as an irritant than a major problem. This attitude persisted during the period of agricultural decline of the pre-war years.

After the second world war, agricultural production was revolutionised. Ploughing was extended, grassland was improved and the old spoil heaps were disturbed. Changing methods of grass conservation were rapidly taken up in an area where hay making was notoriously difficult, without thought of any toxicity which might result. Numerous diggings for fluospar were causing extensive contamination of agricultural land. An amalgamation of these factors lead to outbreaks of poisoning which became of major importance to a farming community moving towards a high input production system, in which failure had serious implications.

Subsistence farming was no longer an option and bankruptcy the potential outcome of lead poisoning outbreaks. In this climate, it was inevitable that veterinary practitioners were pressed by clients for answers to specific problems and practitioners in turn required support for their diagnoses. The VIC's satisfied the needs of both parties. They had the opportunity, the interest, and the laboratory support necessary to fulfil this role and were largely responsible for quantifying the extent of the problems and publicising them so that the farming community could make the necessary changes to their agricultural practices.

Without the involvement of the VIC's it is doubtful if some of the lead poisoning outbreaks described would have been identified and many more animals would have died. Not only did the VIC's staff collect and analyse samples and produce quantitative results, they also looked at the overall situation and advised on ways of alleviating the problem.

Enquiries over the years showed that the most important and continuing hazard to grazing animals, within the confines of the ore field, was due to disturbance of the fragile plant cover of the rakes. This danger was found to continue unless there was revegetation of the scarred surface. Until then, the wind continues to distribute the fine powdered particles produced by the frost disintegration of galena. It was demonstrated that spoil heaps and small hillocks should not be disturbed and that changing the lay-out of fields, by removing walls and widening gateways for larger machinery, would also damage the indispensable plant cover.

Novel methods of establishing vegetation by reseeding and the sowing of new varieties of metal-tolerant grasses, may prove to be of particular importance for agriculture in this area. If the methods are efficacious, it may be possible to allow some degree of disturbance of contaminated land.

Hyperaccumulator plants may also have important functions in the removal of certain metals - so called "green remediation". However, although there are reports of use of bio-accumulators in cadmium and zinc contaminated soils, none have so far been found for lead.

The difficulties of measuring and pinpointing sources of vegetation after harvesting is highlighted in this work. It is difficult to identify, within a silage clamp containing several tons of material, exactly which focus is highly toxic and whence it originated. The redistribution of lead contaminated soil by animal movement was established when it was shown that the stocking of larger fields with cattle and sheep results in dispersion of the soil. Work on the ingestion of soil by ruminants (Thornton and Abrahams 1983) shows that large quantities are taken up under normal conditions. Grazing cattle may ingest from 1% to as much as 18% of their dry matter intake and sheep may ingest up to 30%. Under Derbyshire conditions, the amount of soil ingested on eleven farms varied from 2.1% to 4.4% of the dry matter intake.

Improvements in the methods of silage making to reduce soil uptake were advocated because a better quality product results in improved rumen fermentation and reduces the waste of unnecessary transport (Hayes 1978).

Faecal sampling of a group of cattle at risk and the subsequent lead analyses can be carried out rapidly. If the cattle have been grazing for a sufficient time, faecal values will reflect the uptake of lead. Barltrop (1975) considered the blood lead concentrations in establishing the uptake of lead by a human population. In the case of cattle faecal lead values were found to been as valuable an indicator as were blood values (Thornton et al unpublished data).

The results of the VIC's involvement lead to improved agricultural methods at, or shortly after outbreaks. The public was informed and wider-ranging remedial action was instigated. A Lead Rakes Project Steering Group of the Peak Park Planning Board is at present assessing the risks to farmers from old mining sites in the Peak National Park. A study of the ecology of the surviving lead rakes is being undertaken and decisions are to be made on the choice of those to be designated as Sites of Special Scientific Interest. Advice will be given to stock owners on the advisability of grazing the rakes within the Park.

Further geochemical mapping of the area is about to be completed (Flight et al 1994). This high resolution mapping should prove be of value in making decisions on land use in the ore field. A further development is to be the creation of maps of the heavy metal pollution of land by the Soil Survey and Land Research Centre. The Spatial Environment Information Centre for modelling the Impact of Chemicals (SEISMIC) may have some application for special local needs.

Conclusions

Pollution caused by lead has been studied at eight levels by the VIC at Sutton Bonington:-

1. The release of the pollutant into the environment. The observations following the disturbance of the protective surface soil covering have been described.
2. The concentration of the pollutant in the environment. Studies have been made of the lead levels in the soil, grass and fodder.
3. The measurement of blood, milk and tissue lead concentrations in individual ruminants.
4. Measurement of the uptake of lead by grazing animals. This has been estimated and the total intake of two dairy herds has been calculated during the period that the herds were being fed lead contaminated fodder.
6. Studies of the damage to organs and systems.
7. Advice and remedial methods to reduce the levels of lead contamination in food ingested by ruminants.
8. An overall effect on subsequent government improvement measures.

V. REVIEW 0F THE INVESTIGATION OF OTHER TOXICITIES

RELEVANT TO THE REGION

Introduction

This chapter will describe the investigations carried out on those toxicological problems that were of immediate relevance to the EMR. These would be of sufficient importance to require further enquiries into the severity of the losses and time allocated to discover the aetiology. Results were communicated to the veterinary surgeon attending the animals with all speed to aid treatment of the survivors and to curtail the losses. In the case of certain poisonings of food animals, regulations required the notification of local medical authorities and other MAFF departments in the EMR.

The day-to-day work of a VIC is undefined and a toxicological enquiry could occur at any time folllowing a sudden call - but in other cases, there would be only slow realisation of the severity of a toxicological problem. The relatively high economic value of farm livestock in the UK has generally ensured that some explanation was sought and given concerning the losses. In retrospect, certain diagnoses can be seen to have been unsound. The condition known as "yellows" in pedigree rams caused concern and became at the time a matter of intervention in the export of such animals. The condition was mis-diagnosed as leptospirosis until 1956.

Losses in wild life attracted immediate attention from land-owners in the case of economically important game birds, but the scale of mortality of swans on the Trent was appreciated only slowly.

A successful diagnosis was not always achieved and the aetiology of disease conditions and of specific lesions would remain unknown after many years of work. The prolonged investigation by Sutton Bonington VIC, together with the Institute of Ophthalmology of the University of London, of a congenital nuclear cataract of calves (Ashton et al 1977) has not been described elsewhere in the world literature since this publication. Nevertheless, the condition continued to occur on one of the farms in an area of established chemical pollution, (Herd II of this publication) until 1988. The original discussion suggested that the condition resulted from the action of unknown environmental factors and this statement remains unchallenged.

Similarly, cases of blindness of dairy cows due to retinal lesions were investigated by Sutton Bonington VIC (Clegg et al 1981; Bradley et al 1982). Although toxic agents were sought in a generally chemically polluted area, the cause of this lesion remained obscure. Interactions between dietary components may increase trace element requirements, or on the other hand, allow an increased tolerance to otherwise toxic elements. This leads to complications in arriving at a diagnosis based on tissue analysis of an organ remote from the site of the pathological change. Cattle with hypocupraemia caused by a high molybdenum intake do not necessarily exhibit raised liver Mo values (Dick et al 1975; Mills et al 1978). The significance of hypocupraemia and decisions on the necessity or otherwise of treatment, proved difficult to ascertain in the case of healthy grazing cattle with raised boron blood concentrations.

These illustrations show that the investigation of toxicological problems is not always straight-forward and in some cases especially, those where no previous episodes of toxicity has occurred, prove difficult to diagnose.

A. *COPPER POISONING OF SHEEP*

Copper poisoning of sheep is an example of a disease associated with intensification. The research that followed the first diagnoses was necessary in order to reduce the scale of the losses that were occurring. The investigation of the circumstances of outbreaks, and the work which followed, proved to be models of applied research. Before intensification, Ellenberger and Hofmeister (1883) recognised that sheep were extremely susceptible to copper sulphate. Boughton and Hardy (1934) in Texas and later Naerland (1948) in Norway, recognised the dangers of supplementing sheep minerals with copper sulphate.

In the UK, occasional cases of copper poisoning of sheep result from a variety of other sources. Fincham (1945) of the VI service described losses following the use of copper oxide sprays in Kentish orchards in which sheep were later allowed to graze. However, the importance of maintaining low copper levels in all the constituents of a sheep feed was not appreciated in the UK. The ability of sheep to accumulate dangerously high concentrations of copper in their livers when fed dry rations was not recognised.

Clegg (1956) described the result of this accumulation and the consequently high liver copper values which followed. This paper described the generous feeding of a mineral mixture containing 1,300 ppm copper. The deaths of sheep in excellent condition, often during their preparation for shows, were well known at that time. Pedigree breeders spoke of the deaths as being due to "yellows", or else they accepted an incorrect diagnosis of leptospirosis.

The danger of feeding copper-rich mineral mixtures was recognised following this publication and commercial feed manufacturers took rapid measures to reduce copper levels in a complete ration to only a few parts per million. Within a short time, Pearson (1956) described similar losses but stated that the calculated intake in his case was considerably more than in the case described by Clegg (1956) and could have been as great as 1.2 g daily (Pearson, K L - personal communication).

The scale of losses amongst sheep fed concentrates and dry feed became a serious problem in animals housed for any length of time and this was often the case in sheep kept on trials. A particular research project on the physiology of induced oestrus in ewes was put at risk (Lamming, E - personal communication).

EEC regulations introduced in 1984 required that copper levels in sheep feeds should be reduced to between 5 and 8 mg/kg (ppm). The maximum safe concentration for rations had been accepted in the trade as 15 ppm. The Feedingstuff Regulations (1991) stipulates that the maximum copper level in sheep feeds should be 15 mg/kg. No further changes to these regulations were considered. However, because of the great susceptibility of certain breeds when fed dry concentrate feeds, it was advised that the following notice should be attached to the bags of sheep feedingstuffs :- "Advice should be sought when sheep are being fed high levels of compounds for extended periods of time. This is because sheep are susceptible to copper toxicity when fed on high levels of compounds due to a higher absorption of copper, both from naturally occurring or added sources. This problem may occur particularly with milking sheep and certain pure breeds including their crosses which are prone to copper toxicity."

The main source of copper in sheep concentrates was known to be present in the protein and manufacturers found considerable difficulty in finding sources with sufficiently low values. The trade considered the EEC levels to be impractical to maintain using standard raw materials for their formulations. One manufacturer also maintained that although the danger of copper toxicity existed for housed sheep, most hill flocks were of low copper status.

The trade wished to avoid as far as possible any extra compounding and labelling of bags of feedstuffs. Large numbers of analyses were carried out to determine the copper content of raw materials. Many high values were found to have been incorrect but these had been accepted. New calculations were made for the total copper content of formulae and the number of cases of poisoning recorded in housed sheep was reduced.

VIDA (1983) reported that cases of sheep copper poisoning were becoming more frequent. This followed the mis-use of cattle minerals which had been fed to sheep. Other causes included the injudicious administration of copper containing compounds to flocks where a low copper status was suspected or only presumed to exist. The Veterinary Investigation Surveillance Report (1995) reported a marked increase in the number of incidents of copper toxicity compared with the three previous years. Cases were related to the large quantities of concentrates fed to ram lambs for long periods, for example perhaps soon after birth in January until the time of sales in September.

Gaiger (1917) had described a paralytic sheep disease in Peru known as "renguera" which was causing considerable economic loss. Gaiger believed that the condition was caused by a coccus and there were no enquiries into either possible poisoning or deficiencies. The inspired work of Bennetts in Western Australia proved to be the mainspring of the advances in the treatment of such ataxia of lambs by dosing the pregnant ewe with copper (Bennetts and Chapman 1937). Eden (1939) studied the effects of the total copper intake of sheep on their blood copper concentrations.

Innes and Shearer (1940) wrote the classical description of the pathology of 'swayback' or neo-natal ataxia of lambs using Sutton Bonington VIC as a base whilst working on the same farms. Further work followed on prevention, first by carrying out weekly drenching and then by the intravenous injection of copper sulphate. This proved to be both impractical and unsatisfactory because of the dangers of copper poisoning. Catching the same hill ewe without fail, on successive occasions, proved to be time-consuming and exhausting.

H H Green of the CVL continued the fortunate liaison with the farmers who were interested in 'swayback' prevention. Twenty recently mated ewes from a severely affected farm were taken to the CVL and stall fed a ration containing the low copper content of 5 ppm/DM. In the control ewes remaining on the farm, 20% gave birth to lambs affected with 'swayback'. None were affected of those born

to the ewes over-wintered at the CVL. The next year, the trial was repeated but the CVL ewes were fed hay from the farm of origin. The numbers of 'swayback' lambs were the same in both groups with an incidence of 15% (Hunter et al 1945, Green 1947). Cunningham (1959) in New Zealand described a copper preparation which had been found suitable for subcutaneous injection.

Subsequently Allcroft, Clegg and Uvarov (1959) established the protocols for the use of two different copper preparations by injection and the procedures to avoid overdosing. The trials were again carried out in north Derbyshire and with the participation of one of the original members of the farmers' association. The work had established the flock blood copper concentrations found when swayback was known to occur. No cases of copper toxicity were found in the trials carried out with these hill sheep flocks where the breeds used in the trials were predominantly Derbyshire Gritstone and Lonk and Swaledale crosses.

Sutton Bonington VIC provided a swayback forecast for the EMR which was timed to help the flocks in north Derbyshire (Appendix B). The forecast was based on the number of days of snow that had already covered the ground. This allowed shepherds time to carry out the injection of the copper preparation at the critical time of mid-pregnancy (Allcroft, Clegg and Uvarov 1959). This judicious treatment of deficient flocks reduced the possibility of copper poisoning occurring.

In 1961, a further trial using the CuCaEDTA injection was carried out in the flock where the 1958 trial had been conducted. The trial was to assess the increased dose of copper present in this new formulation *Coprin,* equivalent to 50 mg Cu, in place of the 45 mg Cu present in the earlier glycine formulation *Copper "45" Injection,* Glaxo (Allcroft et al 1959). There had been unconfirmed reports of sporadic deaths of ewes resulting from copper toxicity following the use of the commercial formulation (Ford, E J H - personal communication) and suggestions were made that the 50 mg dose should be reduced.

Details of the 1961 trial are given in the Tables 20 and 21. Forty-six pregnant ewes were injected by the intramuscular route in mid-January - a week earlier than in 1958, with *Coprin* and 47 ewes were designated as controls. Lambing commenced in early April. Table 20 shows the blood copper values found in the ewe flock one month later on February 14. Table 21 shows the number of neonatal and delayed cases of "swayback" occurring in the control ewes, including two sets of twins. Diagnosis was confirmed by the demonstration of demyelination and neuronal degeneration (Terlecki,S - personal communication). The table also gives the copper concentrations found in the central nervous system of affected and of the control lambs of 6-12 days of age which were killed. The blood concentrations of the 18 dams which gave birth to affected lambs were below the mean of those of the treated ewes in mid February - 3.14 μ mol/l compared with 13.16 μ mol/l.

The liver copper concentrations of lambs affected with `swayback` were usually found to be below 235 μ mol/kg. The finding of the solitary raised value of 1196 μ mol/kg in the case of lamb from dam 84, may be explained by possible contamination of tissues during the process of sampling, or possibly the 40-day- old lamb had consumed copper-rich matter.

This later trial was considered to have been successful and to have demonstrated the value of the product and the safety of the raised copper level present. Other trials carried out elsewhere with young cattle in the treatment of hypocuprosis, showed the superiority of the product and nation-wide extensive sales were to follow. Later, Yeoman (1983) reported on the use of cupric oxide needles given to pregnant ewes *per os* and on the reduced mortality suffered by their lambs.

Control ewes		Injected ewes	
Number	Blood Cu (µmol/l)	Number	Blood Cu (µmol/l)
65	3.15	214	17.2
36	4.6	237	12.6
18	4.0	205	12.6
33	1.5	209	15.6
21	4.6	242	12.6
11	4.6	250	12.6
75	4.0	246	9.3
68	4.0	204	15.6
13	4.6	218	12.6
44	4.6	216	12.6
78	4.0	211	12.6
76	4.6	217	12.6
80	4.6	207	12.6
83	3.5	202	12.6
81	6.3	201	14.2
79	3.15	247	11.0
77	4.0	249	12.6
84	4.6	244	14.2
85	3.15	236	15.7
86	-	254	12.6
87	1.5	206	11.0
88	3.15	215	14.2
89	3.15	230	12.6
90	3.15	223	15.6
91	3.15	224	12.6
92	2.2	1	11.0
93	3.15	2	12.6
94	3.15	3	12.6
95	4.6	4	14.2
96	4.0	5	12.6
97	4.6	6	12.6
98	4.6	7	14.2
99	6.3	8	11.0
100	4.6	9	-
82	3.15	10	12.6
326	4.6	11	12.6
327	7.9	12	12.6
328	3.15	13	11.0
329	4.6	14	14.2
330	4.6	15	12.6
331	4.6	16	15.6
332	1.5	17	14.2
333	-	18	12.6
334	4.6	19	12.6
335	4.6	20	12.6
336	4.6	21	14.2
337	3.15	-	-
Mean	**4.00**	**Mean**	**13.05**

TABLE 20 Blood copper concentrations of ewes in the CuCaEDTA trial.

Normal range 12.6 - 18.9 µ mol/l.

TABLE 21 Details of the 1961 CuCaEDTA trial in a ewe flock, the copper status of the dam and of the lambs and the concentrations found in the tissues. Blood copper concentrations in μ mol/l and tissue concentrations in μ mol/kg.

(Normal range of blood copper 12.6 - 18.9 μ mol/l

" " " liver copper 300 μ g/kg - 8,000 μ g/kg

C – control ewes, * - treated ewes, d o - day old, NE - not examined).

Dam	CNS Gross lesion	Histo -logy	Blood Cu	Liver Cu	Grey matter Cu	White " Cu	Cord Cu	Clinical Findings
33 C	++	+	-	63	58		55	Swayback
82 C	++	+	-	32	-	-	-	Still-born
88 C	-	+	-	63	39	<11	17	Twin dead
336 *	-	-	-	2200	204	132	94	Found dead
331 C	++	+	-	63	20	27	16	Twin(1)died
331 C	+	+	-	58	68		16	Twin(2)died
202 *	-	NE	-	1020	116	220	-	Still-born
327 C	-	?	-	74	-	-	-	Unable to Stand
79 C	-	+	-	520	20		80	Found dead
79 C	-	+	9.5	150	22	30	37	Swayback 2 d o
91 C	-	NE	-	63	38	72	36	Twin and weak
? ?	-	+	-	520	36		26	?
18 C	-	-	-	47	39	39	22	Enteritis 4 d o
68 C	-	-	-	33	36	83	42	Still-born
68 C	-	NE	-	35	69	28	30	Still-born
95 C	-	-	-	44	198	49	36	Still-born
? ?	-	-	-	94	61	41	40	Died small
? ?	-	-	-	60	63	17	36	Died small
? ?	-	-	-	3780	1780		92	Found dead
207 *	-	-	11.3	990	94	116	91	Sacrifice 6 d o
97 C	-	-	11.3	86	80	32	<11	" 6 d o
81 C	-	-	6.3	112	100	85	61	" 3-6 d o
78 C	-	-	7.7	63	39	32	25	" 3-6 d o
77 C	-	-	6.3	104	100	39	26	" 6+ d o
215 C	-	-	1.6	1230	228	146	83	" 6+ d o
? ?	-	-	-	2260	220	120	107	?
? ?	-	-	-	94	37	45	44	Still-born
? ?	-	NE	-	-	82		41	Still-born
326 C	-	+	-	105	18		16	?
11 C	-	NE	-	126	-	-	-	Triplet (1)
11 C	-	NE	-	86	-	-	-	Triplet (2)
? ?	-	-	-	1150	-	-	-	Liverlesion
88 C	-	+	-	90	82		23	Swayback 40 d o
99 C	-	+	-	97	52		22	" 37 d o
11 C	-	?	-	122	-	-	-	Triplet (3)
10 *	-	-	-	2200	-	-	-	Leg lesion
87 C	-	+	-	35	35		16	Swayback 42 d o
90 C	-	+	-	86	44		14	" 11 d o
97 C	-	+	3.1	61	47		16	" 42+ d o
85 C	-	+	6.3	61	47		25	" "
84 C	-	+	9.5	1196	67		23	" "
? ?	-	+	20.3	520	47		42	" "
100 C	-	+	3.1	107	52		18	" "

Later, numerous reports were received from other VIC's, of losses in flocks following the injection of other copper compounds, including a new nitrogenous copper-complex preparation. Sutton Bonington played little part in these investigations as most hill farmers were advised by their veterinary surgeons to continue to use the copper calcium edetate preparation. Pre-treatment sampling of flocks to establish blood copper values was encouraged for many years. Advice was given to establish the copper status of ewes recently brought on to the farm from other areas of the country.

Dick (1953) demonstrated that molybdenum, in the presence of adequate inorganic sulphate, had a limiting effect on the absorption of copper from the diet. Allcroft and Lewis (1956) reported initial observations on the copper/molybdenum ratio of diets and their influence on the occurrence in the UK of copper deficiency. Later, copper/molybdenum/sulphate ratios were found to be related to the ability of sheep to accumulate copper in the liver.

The seriousness of losses from copper poisoning led to refinements in methods of treatment. The daily addition of ammonium molybdate to the diet proved to be expensive and the possibility of poisoning with molybdenum during the required six weeks of treatment had to be considered.

Humphries et al (1986) reported on the excellent results from the intravenous injections of ammonium tetrathiomolybdate in acute cases of toxicity. These authors recommended treatment of all the remaining members of the flock which were at risk, and they found no adverse effects on lambs born to ewes treated during pregnancy.

In certain breeds such as Soay sheep, the extreme susceptibility to copper poisoning was investigated. The native diet of this island breed is seaweed, which contains copper but also alginates capable of binding dietary copper and limiting absorption.

A range of susceptibility to copper poisoning was found in other breeds - Texel and Welsh were amongst the most susceptible - and Blackface and Cheviot were found to be less so, with the Suffolk breed between. Crosses were found to have a position between the susceptibility of each parent breed. Later, MacPherson et al (1997) were to report the poisoning of Texel ewes grazing pastures with copper values accepted as normal. The significance of the role of molybdenum as an inhibitor of copper absorption would become more apparent.

B. *THE UPTAKE OF IODINE* **125** *BY THE THYROID GLAND OF SWANS*

A study of the deaths of mute swans (*Cygnus olor*) was carried out by Clegg and Hunt (1975) who described salmonella infection in these birds from the grossly polluted river Thame. The value of these birds as monitors of a particular stretch of waterway was realised. The route from a particular sewage effluent and thence to the contamination of the downstream river-weed was clearly demonstrated. Further studies of the health of swans on the river Trent by workers at Sutton Bonington VIC was followed by national enquiries into the scale of lead poisoning of this species (Simpson et al 1979; NCC Report 1961).

Animal thyroid glands had been used in the monitoring of I **129** and I **131** in fall-out from atomic weapon tests and for surveillance around reactor establishments (Van Middlesworth 1958). In the UK, a national investigation had been carried out to determine the levels of radio-nuclide I **129** in the ruminant thyroid glands of farm animals grazing pastures at different distances from the nuclear-fuel processing sites situated in the UK (Ballad et al 1976). During the course of this survey, it was found that low levels of the isotope I **125** were present at certain sites which were distant from both nuclear installations and from other sources of radio-nuclides. No such installation had ever existed within the EMR or close to its borders.

The survey carried out over four years showed raised values of 20-30 mBq (0.05-0.81 pCi) of I **125** per gram of fresh thyroid gland of swans from the river Trent. The origin of this man-made radio-nuclide remained obscure. I **125** is not a fission product and is not known to arise in sufficient amounts in the upper atmosphere, from either cosmic rays or from neutron bombardment resulting from atomic

Position	Number of glands with detectable I **125**	Number of glands examined	Mean and range mBq/g
0-25 km upstream	14	19	96 (ND-333)
0-25 km downstream	11	14	940 (ND-3,700)

TABLE 22 Radio-iodine measurement of the thyroid gland of swans *(Cygnus olor)* living at sites situated above and below the Nottingham sewage outfall . (I **125** in mgBq/g fresh weight of gland. ND-not detected).

Position	Number of weed with samples with Detectable I **125**	Number of samples	Mean and range MBq/g
0-25 km upstream	6	7	9 (ND-28)
0-6.5 km downstream	4	4	63 (55-74)
Outfall	3	3	29 (17-36)

TABLE 23 Radio-iodine measurements of " blanket weed" from the river Trent taken from three sites. (I **125** in mBq/g fresh weight. ND-not detected).

bomb explosions. A possible source was considered to be the effluent from hospitals which had been using I **125** for diagnostic procedures and for radio-immune assays.

A sufficient number of swan thyroid glands were available to carry out the study as many birds were being submitted as part of the national enquiry into mute swan deaths from lead poisoning. These birds represented all the stretches of the upper river Trent.

A preliminary publication by workers at the CVL and Sutton Bonington (Howe, Lloyd, Hunt and Clegg 1984) described the origin of the I **125** from certain sewage outlets and its presence in the food of the predominantly vegetarian swan. The food of the mute swan in this river consisted of the filamentous algae *Cladophora, Spirogyra* and other species, which together are known collectively as "blanket weed".

Later, Howe and Hunt (1984) described the detailed investigation of the river Trent and its tributaries and demonstrated the source of the I **125** from certain outlets (Fig 38). The work revealed the presence of low levels of radio-iodine in large stretches of the river Trent and its tributaries such as the Soar and that much if not all the radioactivity came from the water treatment and sewage effluents in the East Midlands area. They postulated the pathway followed by the radio-iodine from sewage effluent-water reclamation-river water-river weed-swan thyroid. Iodine isotopes were used in local hospitals in the management of human thyroid disorders. They concluded that the a major part of the Trent radio-iodine originated from the effluent of the Nottingham water reclamation works. The possible risks to humans from drinking the milk of cows grazing the banks of the Trent - or from the consumption of fish taken from the river, were considered to be minimal.

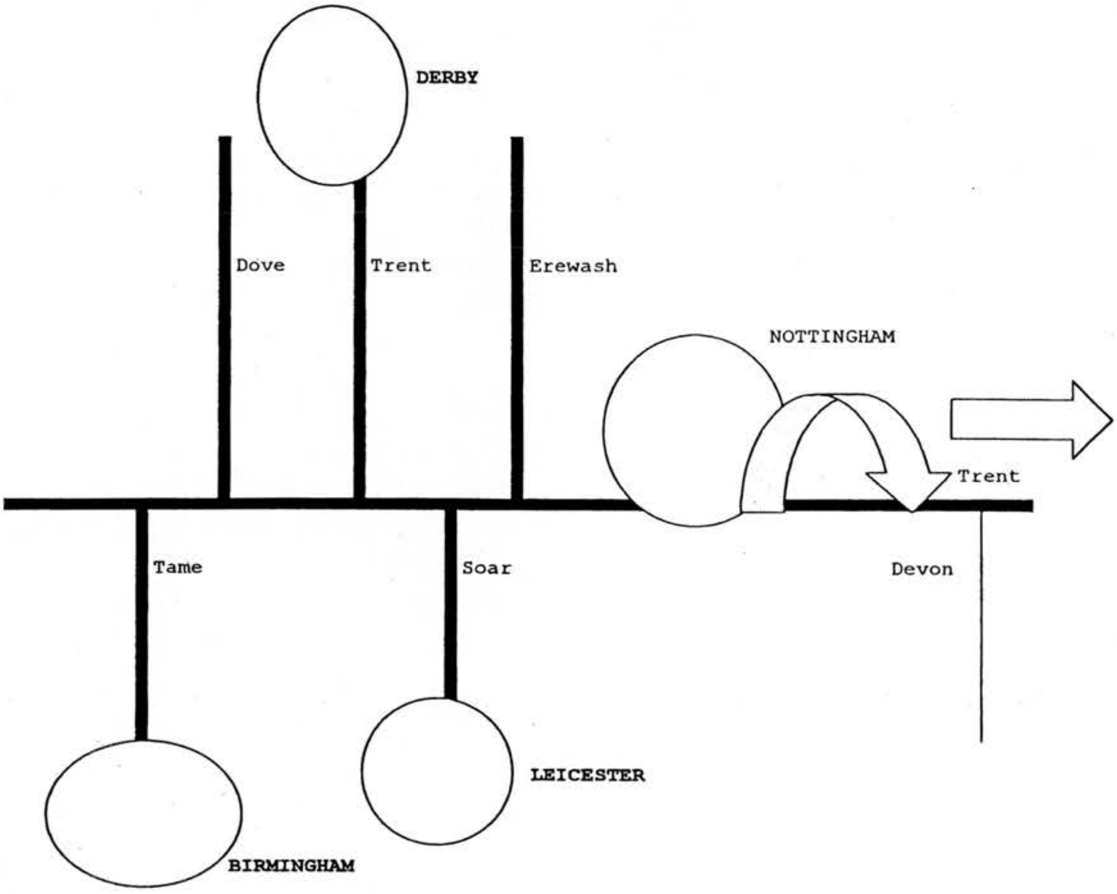

FIG 38 Diagram of the main tributaries of the Trent, the principal towns lying in the catchment area and the position of the single large water reclamation plant outfall from Nottingham (Howe and Hunt 1984).

Table 22 and 23 show the radio-iodine measurements demonstrated in the thyroid glands of mute swans and in "blanket weed" collected at sites where the swans were found along a 32 mile (50 km) stretch of the Trent. The sources of the highest levels were found to be downstream from the village of Stoke Bardolph where the river receives the treated water from the major treatment plant serving the town of Nottingham. The lower values shown in the case of the thyroid glands and weed collected from above Stoke Bardolph, were associated with similar outfalls upstream and which came from the water treatment plants serving the towns of Leicester and Derby. However, the several reclamation plants found on the tributaries upstream are small compared with the huge, single outfall from the town of Nottingham.

Following this investigation, a study of the I **125** contamination of water abstracted for domestic supply in parts of the Thames valley was carried out by Howe and Bowlt (1992). Human thyroid glands were collected at the time of autopsy from erstwhile residents of the area. The investigation showed that 20% of the population had I **125** activities greater than had been predicted.

The developments that followed the initial observations demonstrated the value of extending all investigations into wild animal mortality. The particular circumstances in which the thyroid gland concentrates iodine, allowed the development of this sensitive method of monitoring. The distribution of these birds is also useful. In the UK, the mute swan remains remarkably local on one stretch of river or lake for many months. The territorial dispersion which occurs at the time of mating, separates pairs of birds by about 1 mile (1.6km).

C. OTHER TRACE ELEMENT TOXICITIES

i. INDUSTRIAL FLUOROSIS

Fluorosis in cattle is characterised by dental lesions and by lameness, and these conditions are usually associated with skeletal abnormalities. The continued ingestion by ruminants of small amounts of fluorine over relatively long periods of time results in the clinical condition termed fluorosis. The diagnosis of fluorine poisoning would be made for a more acute poisoning. Some aspects of the systemic effects are similar to those of malnutrition or starvation. In the later and more severe stages of fluorosis, food intake is seriously reduced so that the consequential effects on the growth of young animals, and on the condition and milk production of cows, becomes evident. Fluorine occurs widely, although not abundantly in rocks, soil and water and especially thermal waters. There are several sources of fluorine which may be the cause of poisoning of farm animals and include fluoro-solvent waters, mineral mixtures and fodder which have been contaminated by industrial emissions (Allcroft 1954).

In the UK, naturally occurring waters from deep wells in the lias clays have shown values as high as 4mg/kg, but they have not been considered to be a cause of fluorosis in cattle. Poisoning resulting from drinking fluor-solvent water has not been suspected in cattle in the EMR.

Several cases of fluorosis occurred following the importation of fluorine-rich phosphates from north Africa in 1970. This source of phosphorus was used in mineral mixtures which were fed to cattle. The fluorine content of rock phosphate is high containing from 3 to 4% but in the manufacture of mineral supplements, the fluorine is volatilised and the defluorinated phosphate should contain between 0.1 and 0.5 % fluorine. Ford (1972) of Sutton Bonington VIC reported a case of a poisoned dairy herd and this was followed by a similar investigation in 1974. The animal feeding stuffs industry took rapid and effective action to monitor the levels of fluorine in mineral mixtures and the last case to be reported was in 1975.

The serious problem of fluorosis in the UK arises from contamination of herbage due to pollution of the atmosphere by emissions from certain industries. The scale of the problem of fluorosis associated with industry became a cause of national concern in the late 1950's. The distinguished report of Burns and Allcroft (1964) found that industrial fluorosis was responsible for continuous and serious losses to farmers in the affected localities.

The fluorine content of coal can be variable and similar to the values found in soils (5-500 ppm). Shales usually have a higher fluorine content and so the burning of coal containing a high proportion of shale results in the emission of more fluorine than burning coal of a better quality. Ironstones have a considerably greater fluorine content, which may be as high as 1,200 ppm.

Investigations were carried out in two localities of the EMR where industrial fluorine emissions had contaminated agricultural land and where fluorosis was subsequently diagnosed in local cattle.

1. *Derbyshire.*

Farms situated in the north-east of the county and lying to the south of Sheffield were contaminated by smoke from large plants burning low grade coal (Fig 39). The order of susceptibility to fluorosis of livestock on farms in this locality, was observed to be the greatest in calves, followed by dairy cows, other cattle, sheep, pigs and least in poultry. These differences reflected the management and feeding of each class of animal in the area and did not reflect any susceptibility to given dosage per unit of body weight. These observations were of importance and were reinforced by trials carried out by MAFF on a farm in the neighbouring county of Staffordshire from 1953 to 1961. Attempts were made to feed alleviatory substances to cattle in this trial but with limited success (Burns and Allcroft 1964).

Recommendations were given to the farmers in the areas where fluorosis had been diagnosed. Foodstuffs such as kale were known to be rich sources of fluorine as the large surface of leaf exposed by the shape of the plant could be contaminated. Root-crops were safe as there was no uptake of the element from the soil. Limitations on the time spent by grazing animals on dangerous pastures was suggested but farmers on severely affected farms were found to have changed to keeping pigs or poultry by force of circumstance. Advice was also given on the concurrent hypocuprosis which was found to be severe on many of the same farms. Copper therapy was carried out extensively. In dairy herds where lameness was apparent, blood copper concentrations were low, whereas the affected animals in herds which did not show lameness, exhibited higher blood copper values.

Fig 39 Map showing areas of industrial fluorosis in the East Midland Region

(Burns and Allcroft 1964).

Affected cattle on the farms in south Yorkshire (Towers 1954) and in the adjoining counties of Derbyshire and Nottinghamshire exhibited similar signs (Fig 39). In this area of Yorkshire, large quantities of the locally gained fluorspar were used in the steel furnaces as a flux in the basic open-hearth process.

The loss of condition and reduced yield of dairy cows, which had lived on these Derbyshire farms for two years, were usually associated with lameness and there were similar reports of a seasonal incidence occurring in June and July. The lameness was of the type of "moving" lameness described by Towers (1954) and which was shown first in one leg and then another. Acute lameness following fracture of the pedal bone was also found in Derbyshire.

2. *Leicestershire and Lincolnshire.*

The second area in which fluorosis was investigated, in the EMR was around the ironstone quarrying sites in east Leicestershire and neighbouring Lincolnshire (Fig 39). Fluorosis was first investigated in the vicinity of the sites of the open-air calcining of ironstone, by Blakemore et al (1948). During the war and and until the late 1950's, large burning pyres of ironstone were a feature of the landscape. The fires burnt for many days using coal equivalent to 7% of the weight of iron ore. This coal had a high fluorine content (Allcroft 1954). Cattle on a farm situated downwind from these operations, exhibited dental lesions but no lameness. Green (1946) reported the finding of 2,000 ppm fluorine in a grass sample taken from near these ironstone-calcining mounds and a value of 290 ppm from a sample of straw taken from a stack one mile (1.6 km) distant.

ii. INDUSTRIAL MOLYBDENOSIS

High levels of molybdenum in herbage were found to be responsible for 'teart', a condition of cattle characterised by severe diarrhoea occurring on calcareous soils in parts of Somerset. The soils are derived from the Lower Lias formation and contain > 20 µg Mo/g (Ferguson, Lewis and Watson 1943). Later Allcroft (1952) demonstrated hypocuprosis in cattle grazing pastures where 'teartness' was recognised. The effects of industrial molybdenosis on grazing cattle were first recorded in the UK by Buxton and Allcroft (1955), working from Sutton Bonington VIC. The paper describes the similarities of the clinical signs to those of 'teart'. However, the soils were not derived from the Lower Lias. The authors describe the emission of molybdenum oxides from the stack of a ferro-alloy plant situated in the centre of the town of Glossop, which lies in a closed valley in north Derbyshire . The plant continues to operate until the 1988. Cattle on the hills surrounding the town, and particularly those on the slopes exposed to the prevailing southerly winds, suffered from a molybdenum induced hypocuprosis after the commissioning of the plant in 1949. Parker and Rose (1955) working from the neighbouring VIC in the west midlands, described a similar occurrence due to contamination from an aluminium alloy plant. Within fourteen days of introduction to contaminated grazing, cattle would exhibit profuse watery diarrhoea.

The cause of this diarrhoea which is characteristic of Mo toxicity in industrial cases of contamination has been explained by the action of molybdates in reducing the concentration of the bacteriostatic catechols, by forming complexes with them (McGowan and Brian 1947; Blaschko 1947). Untreated animals lose weight and there is a deterioration in their condition. A seasonal occurrence was found as often diarrhoea commenced soon after the cattle were turned out to grass in April or early May, resulting in their becoming emaciated by the summer. Buxton and Allcroft (1955) described the rapid and satisfactory response to treatment with copper sulphate solution as a drench.

Sutton Bonington VIC continued to monitor the extent of pollution of the pastures and the continuing effectiveness of the specially formulated compound rations for the cattle which contained high levels of copper. In evidence submitted to a local enquiry concerning the nuisance caused by the ferro-alloy plant, the owner of the cattle on one of the affected farms described the history of illness in his dairy herd of 85 cows (The High Peak Borough Council. Appeal by Ferro Alloys Ltd. 8 September 1988). The owner said that the cost of copper treatment was of the order of several hundreds pounds yearly and he considered that infertility occurred, despite the preventative measures that had been taken for the last thirty years. An earlier enquiry in 1977 had resulted in the introduction of a higher chimney but in the opinion of the owner, the effects of the fumes had not lessened, but were now evident over a wider area.

The levels of molybdenum contamination of herbage and of hay made from the same pastures were different in succeeding years as these were dependent on the climate, and the operation of the plant and the types of ore to be roasted.

Table 24 shows the copper and molybdenum values found in grass and hay in the years 1969 and 1970. Bark was taken from a tree on one of the farms (SK 028 945) from the side facing the factory and also from the sheltered side. The differences shown in the molybdenum values found in two bark samples, demonstrated the exposure of the tree to the fumes carried by the prevailing winds from the ferro-alloy plant lying 2.2 km to the south-west. Table 25 shows the results on blood copper and molybdenum values of twelve cows before and after grazing contaminated pasture for 14 days in the early summer of 1970. Nine of the cows showed an increase in blood molybdenum concentrations. The copper concentrations remained unchanged probably because the liver copper reserves of the cows were still adequate after having been built from the winter diet.

Type of material	Copper (ppm/DM)	Molybdenum (ppm/DM)
Hay 1969 sample 1	6.8	13
sample 2	8.0	16
Herbage 1969 sample 1	13.4	38
sample 2	16.5	78
Tree bark facing factory	16	78
sheltered from factory	21.7	10
Hay 1970 sample 1	9	70
sample 2	12	50
Grass 1970 sample 1	21	50
sample 2	17	90

TABLE 24 The copper and molybdenum values of herbage samples taken from the vicinity of a ferrous-alloy plant in 1969 and 197O. (Average or typical values for soils are given for copper as 20 ppm/DM and molybdenum as 2 ppm/DM (Swaine 1969). Copper values for the aerial parts of plants are 6 - 10 ppm/DM and 0.1 - 0.5 ppm/DM molybdenum (Fitzgerald 1954).

Number	Blood copper (µmol/l)		Blood molybdenum (µmol/l)	
	1st sampling	**2nd sampling**	**1st sampling**	**2nd sampling**
1	4.6	4.6	0.83	1.25
2	4.6	4.6	0.83	1.67
3	4.6	4.6	0.83	1.67
4	4.6	4.6	0.42	1.67
5	12.6	6.3	1.25	1.25
6	12.6	17.2	1.25	0.83
7	12.6	7.7	1.25	2.30
8	7.7	7.7	0.42	1.25
9	6.3	4.6	0.83	3.1
10	6.3	3.1	2.1	1.67
11	6.3	4.6	1.25	1.67
12	12.6	30.0	1.60	2.50
Mean	**7.7**	**7.7**	**1.03**	**1.67**
Normal	12.6 - 18.9		0.56 - 1.66	

TABLE 25 The blood copper and molybdenum concentrations of cows before and after grazing for 14 days on pasture contaminated with molybdenum.

iii. LAND RESTORATION WITH PULVERISED FUEL ASH

The middle Trent valley is one of the leading areas of gravel-working in the UK. The huge demand for gravel especially for use in concrete aggregate and road metal has promoted this important extractive industry.

Along the main valley of the Trent, workings are found at intervals along the 50 mile (80 km) stretch of the river from Burton-on-Trent to Newark and at the confluences of the larger rivers, the Dove and the Derwent. The majority of excavations were made below the water table and many worked out sites became lagoons.

The Central Electricity Generating Board had made only limited and local use of these lagoons for disposing of pulverised fuel ash from the power stations situated along the whole length of the Trent. The production of ash was 13 million tonnes in 1986. Approximately 60% of this was sold to the construction industry and the rest was disposed of as waste. Extensive reclamation of these filled-in lagoons was planned for agricultural use and advice was sought on the implications for the health of animals grazing reclaimed land and on the possibility of toxicities occurring (Gillham 1980). Trials took place over several years in the Trent valley (Gillham and Lewis 1971) and an extended grazing trial was undertaken to investigate any long-term toxicological effects and possible lowering of cattle fertility (Gillham and Lewis 1980).

Ash from power stations contains all the elements represented in the soil in which the original plants grew and contains many elements but no nitrogen. The less volatile elements such as boron are increased in quantity. The ash particles physically resemble a fine sandy silt.

The principal site chosen in the EMR was a 6 acre (2.5 ha) area which had been filled with lagooned ash and covered with 9 inches (23 cm) of soil and which had been re-seeded three years earlier. Fig 40 and 41 show the position of the trial field in close proximity to the generating station. Analysis of soil samples showed excessively high boron values reflecting the very high levels found in ash which has not been weathered. The molybdenum and copper values were also high. The poor growth of grass found on such reclaimed land shown in both the figures has been found to be due to salinity and also the high boron content of the revegetated soil (Hodgson and Holliday 1966).

Sampling of the herbage was carried out regularly and showed extremely high boron values with a maximum of 112 ppm/DM (normal range 4-7 ppm). Boron toxicity in other parts of the world has been associated with gastritis in lambs grazing where herbage values for boron were reported to be 28 ppm/DM (Gireer and Ratchman 1966). Fluorine herbage values were consistently raised with levels as high as 8.5 ppm/DM. The boron and fluorine values may have indicated further contamination, which may have been either a stack emission from the nearby power station, or from other airborne dust.

Eighteen-month-old Friesian cattle were grazed on this site in 1967, 1968 and 1969. Observations on the health and live weight gain were carried out. The live weight gains were reasonably constant and the variations could be accounted for by seasonal factors and by the stocking rates.

The cattle remained in excellent condition despite a continuous and dramatic fall in blood copper values throughout each season. There was a tendency for them to become lower each year. Urine fluorine and boron values remained within normal ranges and the levels for

FIGURE 40 View of a field in 1996 which was recovered by infilling with pulverised fuel ash.

FIGURE 41 View of the same field in September 1996 showing the vegetation.

both elements fell over the three years of the trial (Table 26).

In the subsequent infertility trial, a similar plot was chosen with a depth of soil cover of only 6 inches (15 cm). Eighteen-month-old heifers were grazed on this plot continuously until they calved. The animals remained healthy throughout the trial period and their fertility was satisfactory although profound hypocupraemia was diagnosed. This occurred during drought conditions and a surprising finding was that the ash-restored land supported a better growth of herbage than the adjacent unrestored land.

By 1979, there were 1,400 ha of land which was known to have been used for PFA disposal nationally - and 1,000 ha had been restored to agriculture. At this stage, queries were raised by certain workers about the continued farming of this land because of the accumulation in plants of molybdenum, selenium and arsenic (Furr et al 1975, 1976). Work was carried out to determine the residues of the elements found in the carcasses of guinea pigs fed clover, which had been grown on ash (Furr et al 1975). This was extended to include findings in lambs and goat kids fed on similar clover (Furr et al 1978).

However, the gaining of extra acres of grazing became less important as an agricultural priority. Later, the tendency of untended PFA-recovered land to change to birch/willow woodland after thirty years was described (Shaw 1992). In a singular change of priorities, a case has recently been argued for the preservation of certain reclaimed sites. The rapid progress of the plant succession and of the soil accumulation, have resulted in sites rich in orchids and which have become of scientific interest (Shaw 1994).

Year No of Stock	Date	Mean blood values (range)		Mean urine values (range)	
		Copper (µmol/l)	**Molybdenum (µmol/l)**	**Fluorine (ppm)**	**Boron (ppm)**
1967 (9)	22/5	14.3 (12.6-17.2)	0.37 (0.21-0.42)	5.5 (4-7)	1.14 (1-2)
	22/9	10.2 (6.3-16.0)	0.62 (0.42-1.02)	6.8 (5-9)	3.29 (2-5)
1968 (12)	30/5	13.0 (11.0-16.0)	0.83 (0.63-1.25)	-	-
	3/10	8.5 (6.3-14.2)	0.62 (0.42-0.84)	6.0 (4-8)	1.33 (1-2)
1969 (11)	27/5	12.6 (7.7-17.2)	0.06 (0.42-0.84)	5.5 (4-6)	<1.0
	1/70	4.6 (3.1-9.3)	0.72 (0.42-0.84)	3.9 (2-5)	<1.0
Normal		12.6-18.9	0.52-1.66	?	?

TABLE 26 Cattle grazing trials carried out on pf ash recovered land (1967- 1969) showing blood copper and molybdenum concentrations and the urine fluorine and boron values (urine fluorine and boron values corrected to SPG 1.03).

D. *THE POISONING OF WILDLIFE*

i. THE POISONING OF WILDLIFE BY PESTICIDES

The Select Committee on Estimates Report on Agriculture (HMSO 1961) informed the Minister that his department had been negligent in not obtaining sufficient information about the grossly destructive side effects of pesticides on various forms of wild life. Further, it found that the Ministry's notification scheme and safety precautions were gravely inadequate. There were many reports of spectacular losses in wild life in the arable areas of the EMR resulting from the use of chemical seed dressings. A correspondent of the newspaper *'The Guardian'* (15 August 1967) described a plot of 1,500 acres (600 ha) in Lincolnshire, where six or seven thousand birds were reckoned to have died.

At that time, the responsibility for research into the effects of chemicals in agriculture was divided between four departments - the Medical Research Council, the Agricultural Research Council, the Nature Conservancy and MAFF. Sir William Slater, the secretary of the ARC, said that a few poisoned birds and mammals were a minor fraction of those killed by natural causes or the guns of sportsmen. He also stated that "suppliers of agricultural chemicals have done all they can, in conjunction with the MAFF to avoid damage to farm stock and their efforts have been remarkably successful".

Nevertheless, the Select Committee called for the immediate prohibition of three insecticidal dressings which appeared to have done the most damage - aldrin, dieldrin and hepatachlor.

For a number of years, MAFF has operated a Wildlife Incident Investigation Scheme (WIIS) to examine cases of suspected poisoning of vertebrate wildlife and, under certain circumstances, the poisoning of companion animals. The scheme developed from research studies which were carried out after 1960 on the effects of pesticides on birds. That the risks of adverse side-effects of pesticides were assessed before their registration for approval for agricultural use, was granted. Once the products were released on the market, the WIIS proved to be of considerable value in monitoring their use in the field.

MAFF became involved as a result of public concern about the use of organo-chlorine insecticides and the heavy mortality of seed-eating birds which occurred from 1960 onwards. The attitudes of farmers, landowners and government at that time could be described as one of indifference. However, as the scale of pesticide use increased, the scope of investigations widened and losses in other wild species including foxes, were investigated.

The object of the WIIS was thus to identify problems during these early years of the commercial use of those agricultural chemicals which had already cleared under the Pesticides Precaution Scheme. In some cases where there was evidence of misuse or abuse of a pesticide, the results were used to enforce legislation. The Control of Pesticides Regulations (1968) and later the Food and Environment Protection Act (1985) had regulated the supply, storage and use of pesticides. The provisions of both the Protection of Animals Act (1911) and the Wildlife and Countryside Act (1981) made the poisoning of wildlife species illegal.

Sutton Bonington VIC took a leading role in wildlife enquiries over many years. The organisation of the initial collaborative procedures within MAFF was based on the established procedure used at the VIC. The first joint procedures involving the VIS, CVL, ADAS and the Pest Infestation Control Laboratory of MAFF commenced in 1976. After preliminary trials in the EMR which demonstrated that the liaison worked, the scheme became national (Hardy, Fletcher and Stanley 1986).

The WIFF measures usually occurred in three steps. First, a member of the public would find a dead or ill creature and this would be reported to a MAFF official. If there was a likelihood of pesticide poisoning having occurred, a decision would be taken to investigate the case. A field officer would visit the site where the loss had been reported and collect specimens for *post-mortem* examination at the VIC. The VIC would report on the microbiological findings and in the majority of cases, tissues would be submitted to the ADAS Central Laboratory for chemical analysis. Finally, collation of results followed and possible diagnoses were considered in view of the post-mortem, bacteriological, virological and parasitological findings. Because the toxic levels of many agricultural chemicals for wild life had not been established, mortality would only be attributed to a pesticide if tissue residues were raised for this compound and if this could have resulted from a recent exposure. However, even years later, the LD 50 values of many pesticides and other chemicals had not been established for many species (Grieg-Smith et al 1990).

Incidents involving the use of the cyclodiene insecticides, aldrin, dieldrin and heptachlor, caused extensive losses in the cases investigated at Sutton Bonington VIC in the late 1950's. Insecticidal treatment of grain was an especial hazard to granivorous birds. Their predators also died from secondary poisoning following the accumulation of residues from contaminated prey. The use of dieldrin as a seed treatment was progressively restricted until its use was withdrawn in 1975. The national figures showed only two cases of dieldrin poisoning after this date (Stanley and Bunyan 1979). Heptachlor was also withdrawn from use in 1964 and no further cases of poisoning by this compound were recorded.

DDT was widely used in the 1960's and caused the deaths of many thrushes (*Turdus philomelos*) and blackbirds (*Turdus merula*) The residue levels of DDE, the principal metabolite of DDT did not fall over a 20-year review period. DDT was finally withdrawn from agricultural use in 1984. The withdrawal of the cyclodiene seed treatments followed the introduction of two new organo-phosphorus pesticides to control heat bulb fly.

A recent report (MAFF 1995a) concluded that if a pesticide is used in the approved manner, there is negligible risk to wildlife and other animals. The main problem continued to be the deliberate and illegal abuse of a wide range of pesticides to poison invertebrate animals.

ii. POLYTETRAFLUOROETHYLENE (PTFE) POISONING OF WILD BIRDS

Blandford et al (1975) working at Sutton Bonington VIC described the concurrent death of cockatiels and respiratory disease of a human in a domestic situation, following the inhalation of the products of pyrolysis from a pan coated with polytetrafluoroethylene (PTFE). The gross and histological findings in the cockatiels were found to be similar to those found in a later investigation into the deaths of free-living birds. This enquiry took place around a factory in a small town where there was close juxtaposition of houses and small factories (Annual Report Sutton Bonington 1976).

Wells (1982 and 1983) and Lyman (1986) have more recently reported further cases of inhalation toxicity by PTFE. Forbes and Jones (1997) have found further sources of the PTFE as potential dangers in the management of cage birds. These included PTFE-coated baking foil and PTFE-treated heating lamps used in the nursing of sick animals.

In March 1975, the VIC received a report of the death of all nine of a flock of pheasants (*Phasianus colchicus*). The birds had been in good health and were penned in a small garden. *Post-mortem* examination showed a severe oedema of the lungs and hyperaemia of the heart and lungs. Histology of the lungs showed a disruption of the epithelium lining the atria, exudation of serum and fibrin in the tertiary bronchioles and the parenchyma was filled with blood. Unusual whorl-shaped structures were present in the alveoli.

In December, the VIC received a report of the deaths of further pheasants and bantam fowl together with numerous wild birds in the garden where the previous losses had occurred. Fluttering and dying birds were seen to fall from an ivy-covered wall nearer to the factory and numerous carcasses were also found in a neighbouring playground of a school. The species found included sparrows (*Passer domesticus*), robins (*Erithacus rubecula*), blackbirds (*Turdus merula*) and song thrushes (*Turdus philomelos*).

Post-mortem examination of these carcasses showed similar gross and histological lesions. Fig 42 shows the lung oedema and hyperaemia of the heart and liver found in a song thrush (*Turdus philomelos*).

Enquiries were made concerning the factory and it was found that its purpose was the manufacture of industrial racking. The cleansed metal of the racking was sprayed with PTFE in the form of an emulsion which was then subjected to a controlled series of evaporation, baking and cooling stages designed to fuse the PTFE to the metal. Air vents from this plant were clearly visible from the garden and from the playground.

An enquiry into the processes and escape of fumes was carried out the following June by the Central Unit for Environmental Pollution (Warren Springs Laboratory Report: CR 1203 [AP] 1976). Complete tests for the presence of chlorine containing residues (perfluoro-iso-butylene PFIB) were not successful and the atmospheric conditions of wind and temperature were different at the time of sampling. However, excessively raised temperatures may have occurred in the baking process and the repair of a thermo-couple was followed by a period in which no further deaths of birds were recorded.

The investigation was accompanied by local and national publicity most of which was accurately reported. The satisfactory conclusion of the investigation demonstrated the value of an immediate and helpful attitude to the press (Appendix C).

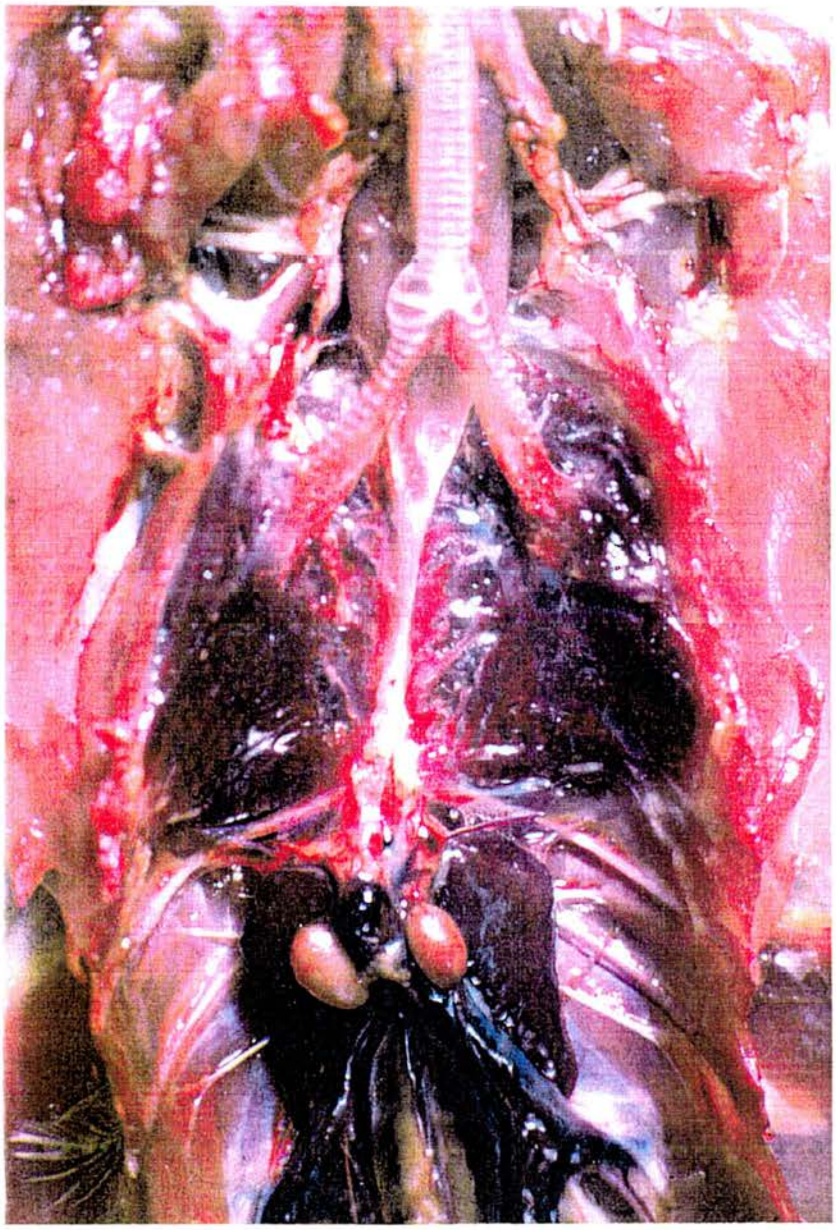

FIGURE 42 The organs of a Song Thush (*Turdus philomelos*) showing lesions of PTFE poisoning.

Discussion

The poisonings described in this chapter were those considered to be of relevance to the EMR. These would be presented as local enquiries and communications within the region were used in following their investigation. Trials of the efficacy of copper therapy in the prevention of neo-natal ataxia of lambs ("swayback") and enquiries into copper poisoning of sheep occupied Sutton Bonington VIC during the fist years described in this work. This was a continuation of earlier trials and commenced in 1957. From 1944 until 1947, a series of observations had been made by members of the Biochemistry Department of the CVL and trials on the use of copper sulphate injections of pregnant ewes were described in a review article by Green (1947). Details of the experiments were never published but were referred to by Allcroft, Clegg and Uvarov (1959). The use of copper sulphate by intravenous injection had been found to be impracticable in the field and also deaths of ewes and cattle following injection occurred.

The successful conclusion of the 1957-1958 trials in north Derbyshire was followed by the early publication of the findings. The use of a copper glycine formulation - *Copper 45 Injection* - which contained copper amino-acetate equivalent to 45 mg copper for the intra-muscular or subcutaneous injection of the pregnant ewe, was found to be safe and efficacious. The pharmaceutical company of Glaxo then reformulated the product using copper calcium edetate.

Further successful trials in 1961 of this final elegant preparation *Coprin*, were made on the same farm for evidence of toxicity and local reactions at the site of injection.

Articles were published in the farming press (Clegg 1965) and advisory meetings were held in north Derbyshire. These were followed by demands for the product and only then did the pharmaceutical product advisers decide to recommend the development of the product. The injection proved difficult to sterilise because of the inclusion of arachis oil and of beeswax. However, sales remained high through out the subsequent years because of the extension of its use in the treatment of hypocuprosis of cattle.

The Sutton Bonington VIC posted a circular to all practising veterinary surgeons each January forecasting the possible severity of "swayback" in the approaching lambing season (Appendix B). This was accompanied by an offer to estimate blood copper on a representative number of pregnant ewes in flocks of unknown copper status. The use of this copper injection rapidly became part of the shepherd's calendar. No reports were received of deaths following injection with this preparation.

Copper poisoning or "yellows" in pedigree rams was a continuing and recognised cause of loss in Lincoln flocks. The removal of all copper from sheep minerals was an effective measure which prevented further losses from copper poisoning in this breed. Clegg (1965) had described the risks from this cause and the feedstuff industry responded rapidly by withdrawing all copper from mineral supplements designed for sheep. Although copper poisoning was to remain a serious cause of loss in dry-fed and housed sheep, an unnecessary source of dietary copper had been removed.

The detection of the radio-nuclide I **125** in the thyroid glands of swans, and tracing its origin, demonstrated the importance of carrying out investigations into the diseases of all vertebrate forms of wild life. Knowledge of the biology of swans had been gained previously during the course of the VIC's local enquiries into lead poisoning and salmonellosis. Liaison with ornithologists and water authority workers facilitated the planning protocols for the sampling of the birds and their environment.

An evaluation of the role of the VIS in this enquiry shows that it was carried out with a dispatch, which can be regarded as having been adequate. The VIC can be seen to have been willing to instigate enquiries into wildlife losses and was prepared by previous collaboration with local workers. The reporting of the presence of the raised I **125** levels in the drinking water of the UK and in the thyroid glands of 2% of the human population can be seen as a direct consequence of the work of the VIC (Howe and Bowlt 1992). In particular, the first reports of measurable amounts of I **125** in the thyroids of humans living in the Thames Valley, lead to concern in the public press (*Observer* February 8, 1987).

The investigation of the industrial fluorosis proved to be effective and followed the early publications of findings in the EMR (Green 1946; Blakemore et al 1948). The important and highly competent National MAFF Survey conducted by Burns and Allcroft (1964) reported on the levels of contamination of pasture in the north of the EMR and adjoining south Yorkshire. Sutton Bonington VIC assisted in trials on the alleviation of fluorosis held on the experimental farm in the neighbouring county of Staffordshire. The problems caused to livestock farms and the mitigating measures to be taken, were publicised by this model survey.

The successful investigations of the localised pollution caused by molybdenum issuing from the stack of a ferro-alloy works, was a precedent for many studies of livestock poisoning by industry (Buxton and Allcroft 1955). The work was cited at an enquiry into the continuing problem as recently as 1988. The response of the VIS to the complaints of the farmers of this community was immediate and adequate. The recommendations for control of the condition were tangible and remained effective for over forty years. The dissemination of information was good and the VIC kept later developments at the plant under observation.

The restoration of land by filling lagoons created by gravel excavation with pulverised fuel ash, was of importance to some farmers in the Trent valley. The initial studies (Gillham and Lewis 1971) showed that the growth of cattle grazing pastures on reclaimed land was adequate despite concomitant hypocupraemia. The results of further investigations into a possible reduction of the fertility of heifers reassured owners that this was normal (Gillham and Lewis 198O). The VIC together with farmer's practising veterinary surgeon maintained an interest in the stock for many years.

Wild life poisoning investigations were given little priority at the beginning of the period described in the thesis. However, national concern about the diminishing swan herds on the rivers in the EMR resulted in rapid official decisions to continue and to extend this investigation. This was followed by the successful legislation banning the use of lead weights by fresh-water fishermen and the re-appearance of swans on the Avon to the delight of countless visitors.

After 1977, there were many successful investigations into the scale of the pesticide and wildlife losses. These investigations were co-ordinated with other departments of MAFF and succeeded admirably.

The Wildlife Incident Investigation Scheme (WIIS) developed from this collaboration and was set up in 1991 with the following aims:-

(a) to advise farmers, game keepers and other land managers on the legal ways of controlling pests

(b) to advise the public on how to report illegal poisoning incidents

(c) to investigate incidents and to prosecute offenders.

Meanwhile the Pesticides Safety Directorate (PSD) was set up to direct campaigns against the illegal poisoning of animals and to publicise the WIIS.

The first report in the UK of the poisoning of birds by polytetrafluoroethylene (PTFE) (Blandford et al 1975) was of significance as a case that demonstrated the importance of joint medical and veterinary enquiries. The diagnosis of polymer fume fever in humans might be made more frequently if any concomitant losses or illness in pet animals were to be investigated. Experience of PTFE poisoning of birds aided the investigation later of extensive losses in birds in a crowded area of factories, schools and housing. This illustrates the importance of pursuing the investigation of all causes of mortality occurring in vertebrate wild life.

VI. REVIEW OF OTHER POISONINGS INVESTIGATED BY THE VETERINARY INVESTIGATION SERVICE

Introduction

This chapter will describe the investigations carried out at Sutton Bonington VIC which proved to be of national importance. The enquiry and its implications, had effects outwith the EMR and could be appreciated as part of national advances in veterinary medicine. In such enquiries, workers at each VIC would be informed about the changing epidemiology of a suspected and novel intoxication.

In the early days of the aflatoxicosis outbreaks in the UK, VIS workers were aware of day-to-day developments and the poisoning in a succession of farm animal species. It was recognised that in such a case of unfolding of national and international events, that publication of new findings should be made quickly. Other mycological enquiries, especially ryegrass staggers of grazing animals, became of interest to overseas workers.

Botulism of animals remained a matter of national importance. Concern about public health issues commenced with the first description of botulism in broilers (Blandford and Roberts 1970) and later in turkeys, and continued until the reporting of bovine botulism (Clegg et al 1985).

In the case of the investigation of the poisoning of ruminants by plants of the *Brassicae* sp, the interest outside was shown by agriculturists and plant breeders.

1. *MYCOTOXINS*

i. Introduction

Fungi (Mycophata) and their metabolic products, the mycotoxins, may occur in foodstuffs and their presence may be the cause of severe outbreaks of illness in man and animals. The class Ascomycetes of the Mycophata include the moulds Aspergillus, Penicillium and Claviceps (ergot) which are all important causes of loss in animals. Outbreaks of poisoning due to *Aspergillus flavus* and to *Claviceps purpurea* have both been the subject of investigations by Sutton Bonington VIC.

Mycotoxins are prevalent contaminants of feed and food commodities. It is estimated that more than 20% of all European food commodities contain one or more toxic metabolites of moulds (Fink-Gremmels 1994). Although clinical cases of mycotoxicoses remain scarce, some workers consider that the economic losses are considerable and result from sub-clinical intoxications which cause reduced weight gain, poor food conversion, impaired fertility and the less efficient immune responses following infections (Fink-Gremmels 1994).

The effects of mycotoxins differ between the species of domesticated animal. The lolitrems affect cattle and sheep - and occasionally horses. Many species were found to be susceptible to aflatoxin. The rat is relatively resistant to poisoning whereas the duckling was found to be extremely susceptible (Carnaghan 1965). Difficulties of arriving at a diagnosis were considerable in the investigations of mycotoxicoses as the clinical signs shown by the animals poisoned with the different groups of mycotoxins were varied.
Aflatoxin was associated with anorexia, ill-thrift, tenesmus and later icterus. Neurological signs were associated with cyclopiazionic acid which is now considered to have been present in the mixtures of toxins present in the early aflatoxcosis investigations. The lolitrems and penitrems are classed as tremorgenic toxins as they produce tremors and the 'stagger' syndromes in ruminants and horses.

A further difficulty in the investigation of mycotoxicoses was that there could be mixture of toxins in one batch of poisonous feed. This could be caused by a foodstuff having being stored in unsatisfactory conditions. A search for one toxin would be complicated by an overgrowth of the original toxin-producing mould by another species, which might itself have been a toxin producer. Such changes could happen between the time of sampling and the time of analysis. Heat treatment carried out by the compounder might also destroy evidence of an earlier mould contamination.

Nutritional deficiencies could also complicate the diagnosis of a mycotoxicosis. Classically, Mellanby (1930) described the difference between the occurrence of convulsive ergotism in human populations with a low vitamin A status, and populations where there were adequate levels of the vitamin and the gangrenous form of ergotism occurred.

The possibility of the occurrence of mycotoxicoses was underestimated by investigators in the UK. Keppler and de Jongh (1964) reported the isolation of aflatoxin from a 40-year-old sample of groundnut and so raised the possibility that the toxin may have been present and its effects unrecognised. The history of exudative diathesis of guinea pigs receiving groundnut, suggest that poisonous batches of meal were imported before the report of Paget (1954). Extensive reviews and descriptions of mycotoxicoses already existed in the literature. The history of yellow rice disease of man was well known and Miyake et al (1940) had isolated the mould *P. citreo-verde* from rice - which was known to have caused nervous signs - and deaths of humans consuming infected crops. The Russian literature contained many references to *Fusarium* toxins (Shapalov 1917). Animals fed infected grain were affected and extracts of the fungus were known to kill frogs experimentally. In the USA, Schofield (1924) investigated a haemorrhagic disease in cattle previously fed mouldy sweet clover. He reproduced the condition consistently in rabbits by feeding mouldy clover hay. The anti-coagulant coumarin was later identified as the toxin.

Investigations involved Sutton Bonington VIC in the early enquiries into the occurrence of mycotoxicoses as a cause of loss in the EMR. A calendar of the investigations made by Sutton Bonington VIC and the other VIC's in collaboration with the Biochemistry Department of the CVL, are shown in Table 27.

1957	Ergotism of sheep	(Clegg 1959)
1959	Ryegrass staggers in sheep	(Clegg and Watson 1960)
1960	Investigation of poult mortality	(Annual Report Sutton Bonington 1961)
1960	Groundnut poisoning of cattle	(Clegg and Bryson 1962)
1960	Immunity of poultry following aflatoxicosis	(Siller and Ostler 1961)
1961	First experimental groundnut poisoning of guinea pigs	(Clegg and Bryson 1962)
1961	Groundnut poisoning	(Loosmore and Harding 1961)
1961	Groundnut poisoning of cattle	(Loosmore and Markson 1961)

TABLE 27 Calendar showing date of investigations into livestock losses due to mycotoxicoses by the Veterinary Investigation Service.

ii. AFLATOXICOSIS

Aflatoxin is the name of the toxic material derived from the fungus *Aspergillus flavus*. It was at first considered to be a mixture of toxins, the composition of which would depend on the strain and the growth conditions of the fungus. Outbreaks of aflatoxicosis caused by consuming feed containing the metabolite of the fungus A. *flavus*, are a world-wide cause of serious livestock loss. These outbreaks are of concern as the metabolites may also be found in animal products, especially milk. The overall effect of the aflatoxins on the immunogenesis of human populations has been evaluated (British Medical Journal 1975).

Outbreaks of animal disease associated with the feeding of groundnut in the past are known. von Wolff (1895) recommended that care should be taken to avoid the purchase of earthnut cakes which are impure or hairy in appearance. Kellner (1915) recognised that castor contamination of earthnut could occur, but he did not think that ricin was responsible for the disease syndromes that were associated with the feeding of this cake. Later, Linton (1927) stated that groundnut meal that had been attacked by mould was particularly dangerous.

The first cases of what was to be recognised later as aflatoxicosis, occurred in turkey poults following the incorporation of a particular shipment of Brazilian groundnut in proprietary compound feedstuffs. This followed the contamination of large batches of feed which were distributed throughout the UK in 1960 and 1961 (Blount 1961).

Groundnut shipments from at least thirteen countries were subsequently found to be poisonous and included those from Brazil, India, Uganda, Tanzania, the Gambia, Zambia, Ghana, Burma and Australia. Carnaghan and Allcroft (1962) reported the presence of an extremely toxic shipment of ground nut from India.

In addition to possessing an acute toxicity of a high order to many species certain mycotoxins also possess carcinogenic properties (Lancaster et al 1961). The fraction Aflatoxin **B** is known to be one of the most potent naturally occurring carcinogens and causes hepato-cellular carcinoma and cholangio-carcinoma of the liver, and in the case of rats, renal adeno-carcinoma (Barnes and Butler 1964). Table 28 shows a calendar of the progress of the investigations into aflatoxicosis in the UK.

In 1960, the VIS investigated the extensive losses occurring in turkey poults. The birds were submitted by owners - usually small farmers - who planned to rear the poults in time for slaughter for the Christmas market. The numbers of birds kept at that time by individual owners were small. Mortality rates as high as 70% were frequent and nationally it was estimated that 100,000 poults died. Losses occurred from a few days to a month-old and most deaths took place at 2-4 weeks.

Date of Investigation

1954 Guinea -pig losses due to "exudative diathesis" (Paget 1954)

1957 Guinea-pig losses associated with Diet 18 (Stalker and McClean 1957)

1960 Reports of turkey "X" disease (Blount 1961)

1960 Toxicity of groundnut for ducklings (Asplin and Carnaghan 1961)

1960 Poisoning of cattle and poisoning of guinea pigs (Clegg and Bryson 1962)

1960 Depression of immunity in poultry flocks (Siller and Ostler 1961)

1961 Poisoning of pigs (Loosmore and Harding 1961)

1961 Poisoning of calves (Loosmore and Markson 1961)

1961 Hepato-carcinoma of rats following feeding of groundnuts (Lancaster et al 1961)

1962 Toxic meal of Indian origin reported (Carnaghan and Allcroft (1962)

1963 Report of aflatoxin like effect on ducklings from bovine milk containing metabolite (Allcroft and Carnaghan 1963)

1964 Aflatoxin established as a cause of carcinoma in rats (Barnes and Butler 1964)

1964 Levels of aflatoxin established in feedstuffs (A Commercial Research Group 1964)

TABLE 28 Calendar of the investigation of aflatoxicosis in the UK.

Sutton Bonington VIC reported one of the first outbreaks in poults fed a home-mixed ration and which was not a proprietary turkey formulation (Annual Report Sutton Bonington VIC 1960). At that time the use of commercial compounds was becoming a more usual practice on poultry farms. A quantity of the poisonous Brazilian groundnut meal that had been incorporated in the feed, was obtained. This sample proved to be of great importance in the evaluation of the first trials of the duckling toxicity test that was to be used for the screening of imported groundnut meal.

The condition was termed "X" disease by Blount (1961). Concurrently, Asplin and Carnaghan (1961) of the CVL described the disease in ducklings. These authors reported at the same time that the common factor was the presence of Brazilian groundnut meal in the compounds which had been fed. Loosmore and Harding (1961) of the Reading VIC investigated disease outbreaks in pigs and later outbreaks in calves (Loosmore and Markson 1961). The calf disease had at first been diagnosed as seneciosis (ragwort poisoning) but both outbreaks were subsequently shown to have followed the inclusion of Brazilian groundnut meal in the feedstuffs.

Clegg and Bryson (1962) working from Sutton Bonington VIC described Brazilian groundnut poisoning in older cattle. The investigation took place in 1960 but publication of the findings was delayed for legal reasons. Fig 43 and 44 show the grossly swollen liver of an 18 month old steer which died from aflatoxicosis after being fed on Brazilian groundnut meal for three months. Fig 44 shows the cut surface of the liver and the extensive fibrosis.

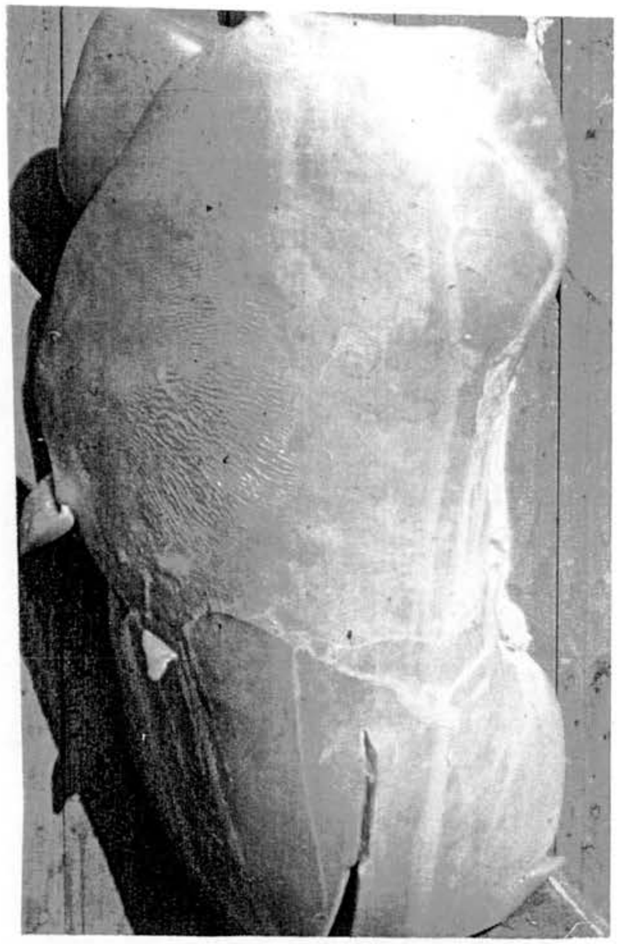

FIGURE 43 The liver of a bullock aged 18 months showing lesions of aflatoxicosis.

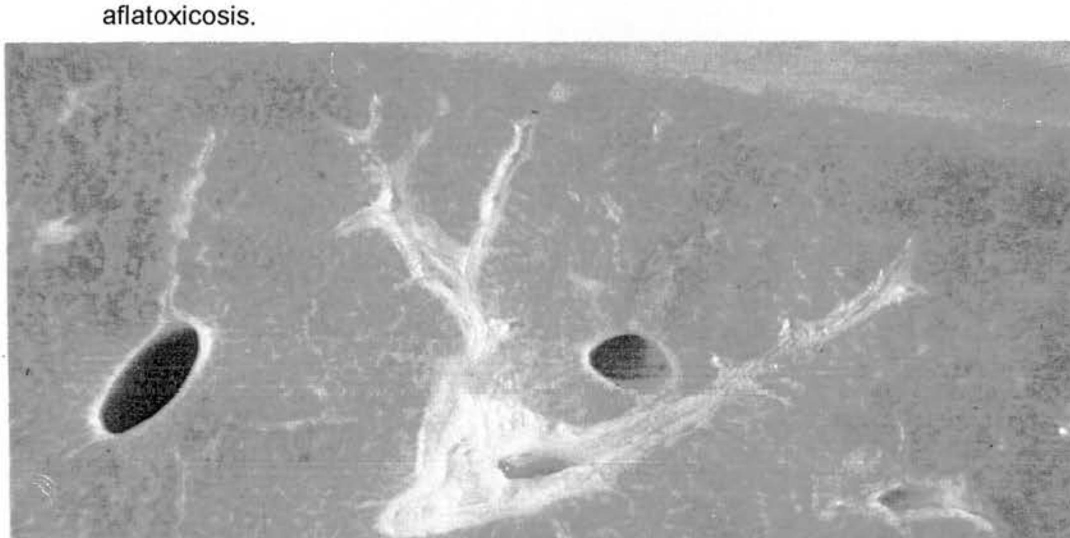

FIGURE 44 Section of the liver of a bullock aged 18 months showing lesions of aflatoxicosis.

Clegg and Bryson also gave the first description of the experimental poisoning of guinea pigs by the Brazilian groundnut meal responsible for the cattle outbreak. Sutton Bonington VIC in common with other guinea pig breeding colonies had experienced unexplained losses during the decade which followed 1954. These losses had always been associated with the feeding of a commercially pelleted diet which consisted of 15% groundnut meal and was known as Diet 18 (Paget 1954; Stalker and McClean 1957). Clegg and Bryson (1962) described the pathology of the experimental poisoning and Paterson et al (1962) reported that the cause of 'exudative hepatitis' of guinea pigs was due to groundnut toxicity. Later, Butler (1966) confirmed these observations using assayed levels of aflatoxin added to feed of guinea pigs.

The discovery of aflatoxin in animal feed and the realisation of the potential public health risks which could follow the consumption of dairy products from cows consuming toxin-containing feedstuffs, stimulated considerable research throughout the world. Allcroft and Carnaghan (1963) reported that when cows were fed a diet containing toxic groundnut material, a toxic factor was secreted in their milk, which caused the same biological effects on ducklings as those caused by aflatoxin. There was particular concern about milk products and particularly those milk powders prepared for use in human milk substitutes. The possibility of an increased susceptibility of babies to this unknown toxin was considered. Groundnuts in shell were found to contain the highest proportion of samples with aflatoxin and this was also detected in shelled nuts and in peanut butter.

Research was later to be conducted on many other aspects of aflatoxicosis and extended into the toxicology of other mould metabolites. There was concern about the possible risks to infants from bovine milk and milk products from dairy herds fed rations containing aflatoxin (Carnaghan and Allcroft 1963).

The economic losses from actual and threatened bans on the importation of shipments of groundnuts suspected of containing aflatoxin, were important at government level. In India (Arora, S P personal communication) there was an added concern because of advanced plans to distribute a national multi-purpose food supplement in the form of a biscuit which incorporated groundnut flour.

The biological tests devised by workers of the Biochemistry Department of the CVL were based on the lethal effects and the changes in the histological appearance of the liver in ducklings. The test proved of considerable value at that time before more colorimetric methods were developed but the sensitivity and precision of this technique were low. Barnes and Butler (1964) induced liver carcinoma in rats by feeding crystalline aflatoxin. Aflatoxin was also shown to produce carcinoma in trout (Ashley et al 1964) and in ducklings (Asplin and Carnaghan 1961).

Work continued on the mode of action of aflatoxin. Feeding trials took place in which MAFF collaborated with certain industrial laboratories to establish the levels in feedstuffs which would produce adverse effects on farm animals (A Commercial Research Group 1964). As a result of this work, the number of outbreaks of clinical disease due to aflatoxin, fell in all species of farm animal. However, some farmers continued to purchase concentrates in bulk and to mix their own feeds. These owners remained at risk from aflatoxicosis until the screening of shipments of groundnut meal at the ports commenced (Patterson and Roberts 1979).

Reciprocal visits of advisory workers, nationally and internationally, were arranged and these led to early improvements in methods of harvesting groundnut crops and in the subsequent drying, threshing, storage and transportation. These changes resulted in improvements of the unfavourable conditions which allowed the growth of the mould in the kernels (cotyledons) of the plant.

Later, there was concern about the association between the incidence of primary hepatoma in man in those African countries where there was a both a high carriage rate of HBAg and exposure to aflatoxin in the diet. This led to demands for the improvement of harvesting methods of the crop for human use (British Medical Journal 1975). Outbreaks of aflatoxicosis in humans were reported in villages in western India until as late as 1975 (Krishnamachari et al 1975).

The influence of mycotoxins on the immunity of farm animal populations was unfortunately not investigated sufficiently. Experimental work on immuno-suppression caused by aflatoxin was summarised by Coulombe (1993) and Pier et al (1979). Experimentally, Boonchuvit and Hamilton (1975) described the interaction of aflatoxin and paratyphoid in chickens. Smith et al (1969) described the relationship of aflatoxicosis to the infection of chickens with *Salmonella gallinarum* and Miller et al (1978) studied the effects of the mycotoxin on the immunity of pigs to salmonellosis. Chang and Hamilton (1979) observed the impaired phagocytosis of heterophils from chickens which had been poisoned with aflatoxin.

The clinical signs and lesions in many species of animal produced by aflatoxicosis are similar to those found in cases of seneciosis - or ragwort poisoning. Seneciosis is caused by pyrrolozidine alkaloids. Preliminary searches for these alkaloids were made in the first cases of aflatoxicosis to be investigated, with negative results.

An important case of seneciosis of cattle was investigated in the EMR by Cockburn et al (1955) with the assistance of Sutton Bonington VIC. The findings were published and became the subject of a claim. A considerable sum of money was awarded for damages following the feeding of dried grass contaminated with ragwort. It is of interest that the liver pathology showed lesions which at that time, were considered to be pathognomonic of seneciosis. The growing grass crop was shown to have been infested with *Senecio jacobea*.

A question remains why mycotoxins had not been recognised earlier in the UK as a cause of disease and economic loss. The history of the presence of aflatoxin in samples dating back to the 1920's (Keppler and de Jongh 1964) and the occurrence of Diet 18-induced illness in guinea pigs from the 1950's, suggest that aflatoxin existed in animal foodstuffs before the losses in turkey poults which eventually led to the identification of the mycotoxin.

It appears that outbreaks of aflatoxicosis could have occurred in the UK and that they remained undiagnosed. There was also a failure to appreciate the overall effects of aflatoxin on the immune response of domestic animals (Sharma 1993). VIS workers investigated only a few cases where aflatoxicosis occurred together with outbreaks of salmonellosis or *Candida* sp. Siller and Ostler (1961) described the depression of immunity in aflatoxin-poisoned flocks. This valuable investigation was the only one published in the UK.

iii. ERGOTISM AND "RYEGRASS STAGGERS" OF SHEEP

The two fungi of veterinary importance which cause ergot of grasses and cereals, are *Claviceps purpurea* and *Claviceps paspali*. These are found in a large numbers of host grasses, the most important of which are ryegrasses *Lolium* spp. In the United Kingdom, *Cl. purpurea* is the established cause of ergotism, whereas in New Zealand, the massive infestations of paspalum grass which occur are caused by *Cl. paspali*.

Ergotism

Ergot poisoning can be traced to some of the earliest civilisations and ergot may have been used by the Chinese 5,000 years ago in obstetric practice probably for the treatment of post-partum haemorrhage. It was used by both Arab and Roman physicians and by the 17 th century was known to be responsible for visitations of the 'holy fire' (van Rensburg and Altenkirk 1974; Ramsbottom 1953). Tulasne(1853) described the fungus and the life cycle with illustrations of the sclerotia.

Poisoning of livestock following the ingestion of the sclerotia of *Cl. purpurea* has been reported from many parts of the world and a range of clinical signs have been described, including gangrene of the ears, tail and limb extremities, lameness, ataxia and hypersensitivity. Whether ergotism is a cause of abortion in ruminants has been disputed for many years. Appleyard (1986) described eleven abortions in a herd of 38 heavily pregnant cows grazing an infected pasture but the evidence was entirely circumstantial. The experimental poisoning of pregnant gilts with ergot (Bailey, Wrathall and Mantle 1973) did not produce any adverse effects either on the maintenance of pregnancy or on the implantation of the blastocyst.

Historically, cases of convulsive ergotism of animals have been known to occur at the same time as human cases in outbreaks of poisoning due to contaminated grain. Gabbai, Lisbonne and Pourquier (1951) and Latour (1955) have described the spectacular outbreak at Pont-Saint-Esprit in France, where 4 out of 25 cases showed convulsions. Domestic animals which had eaten the same contaminated rye bread, were similarly affected.

The 'honey dew' stage of infection is not considered to be dangerous to grazing livestock (Bradley-Jones 1965), although this is disputed by Mantle et al (1978) who maintain that there is a limited toxicity of the fungus *Cl. paspali* at this stage. There is considered to be no risk from silage or from early hay, but hay made later when sclerotia have developed may possibly be dangerous. However any handling of a dried inflorescence will cause the sclerotia to fall out of the brittle glumes with ease. Edwards (1953) described the disappearance of heavy pasture infestation within forty-eight hours in the autumn following wind and rain.

Ergot not only reduces the yield of infected crops but also contains alkaloids toxic to animals. The most striking manifestation of *Claviceps* infection is the presence of ergots (sclerotia) in the grass seed head. Sclerotia vary in size and shape and they correspond to that of the host plant's seed. Sclerotia of *Cl. purpurea* are black and the inside is a milky white colour tinged with purple around the edge. The earlier production of the 'honey dew' which attracts insects, occurs soon after the florets have been infected. The wind-borne ascospores produced by the germinating ergot, penetrate the ovary of the grass seed and produce a mat of mycelium which wells out of the enclosing glumes.

Modern seed-cleaning methods which are used to treat infected crops should control transmission. Nevertheless, it is known that prior to 1957, infections of the pastures and cereals did occur and infection of nearby barley and wheat were found (Clegg 1959). It was ascertained that the stockowner had sown a cheap grass mixture imported from France (Hughes, E J - personal communication). Infection of wheat is less common than of ryegrass, and barley is only infrequently infected. This is due to the different lengths of time the flowers are open. In 1957, there was extensive infection of pastures with ergot throughout the UK. Crops of rye grown in Lincolnshire in 1957 for the manufacture of a proprietary crispbread were not accepted for this purpose because of severe infection of the standing crop (Clark, R - personal communication).

Jenkinson (1958) described extensive infection of grasses in the south-west of England in 1957. In September, the percentage of infected rye-grass heads reached 88% and by October this was 100%. The sclerotia had germinated as expected in early June and the pastures had then been grazed in the summer. The majority of surviving inflorescences were those that had been neglected by grazing animals during the summer. Conditions in that year may have been exceptional as a record high values for alkaloids in UK was found for ergot from the affected farm in Lincolnshire (Evans, J T R - personal communication).

A value of 0.857% total alkaloids was demonstrated and the constituents were ergotamine, ergocornine and ergometrine with traces of ergocristine and ergokryptine. This was similar to the composition found in Spanish sclerotia that were being imported at that time for drug extraction.

The Port Health Authority of the UK would not release grain for human consumption if this contained more than 0.3% ergot by weight. The EEC (EC) regulations of that time stated that basic seed corn should contain no more than one piece of ergot in a 500 g sample and feed grain should contain no more than 0.1 % of ergot by weight.

In view of the recent banning of the burning of stubble in the UK, it is of interest that claims have been made in the United States of America that this practice may eliminate diseased material, including the overwintering sclerotia of *Claviceps* sp. (Hardisson 1977).

The possibility that the ingestion of ergot could be the cause of 'ryegrass staggers' was discussed by Thornton (1964) working in New Zealand. Cunningham et al (1944) stated that it was popularly believed that this fungus was the cause of the condition. Thornton disproved the theory that the sclerotia were responsible but there still remained a possibility that other alkaloids present at the honey dew stage could be responsible. In New Zealand, di Menna, Mantle and Mortimer (1976) reproduced the staggers syndrome in lambs and calves by administering extracts of the tremorgenic toxin-producing mould *Penicillium cyclopium.* These workers considered that a ewe could ingest enough soil to cause poisoning if it contained sufficient toxin. However, much would depend on the type of soil, the stocking rate and on the response shown by individual animals.

"Ryegrass Staggers"

Ryegrass staggers is a neuromuscular disease of grazing cattle, sheep and occasionally of horses, characterised by tremors and inco-ordination. The condition occurs throughout the world wherever ruminants graze short, perennial ryegrass (*Lollium perenne*)-dominated pastures during the summer and autumn. Infection of the pastures with the endophyte *Acremonium lolii* is known to produce the tremorgenic mycotoxin lolitrem B. A similar mycotoxicosis, fescue lameness of cattle in the USA, causes considerable economic loss and follows the infection of pastures by the endophyte *Acremonium coenophialum*. The lolitrem group of toxins are the known cause of this condition (di Menna et al 1976). Doubt had existed for many years as to whether or not the condition was a manifestation of ergotism.

In outbreaks of ryegrass staggers, the affected animals appear normal but when disturbed show a characteristic high stepping 'rocking horse' gait and will soon fall to the ground - and at once attempt to stand. In the early stages, this is successful and the animal runs further and may collapse in this way several times. Opisthotonos, nystagmus, paddling of the limbs and muscular spasms are found. Mortality is low and in the UK, there are no reports of any associated ill-thrift. However, Fink-Gremmels (1994) maintained that the condition is a cause of serious economic loss both in Europe and in New Zealand.

The condition was first described in New Zealand (Mullins 1941) and then in Australia (McDonald 1942). In the UK, Chesney (1953) described a clinical condition of sheep on the Romney Marsh known locally as *'migram'*. This was characterised by staggering and falling and was thought to occur when sheep were kept on short pasture and were known to have drunk brackish water from the marsh ditches.

Clegg and Watson (1960) working from Sutton Bonington and Leeds VIC's reported the first case of ryegrass staggers affecting sheep in the UK. The investigations were carried out in the exceptionally dry summer of 1959. The drought was severe in the EMR and by late summer, the pastures were bare and brown. Searches for ergot sclerotia were unsuccessful. Analysis of the liver of an affected sheep was negative for the presence of ergot alkaloids (Evans, J T R personal communication). Gallagher et al (1981) described the isolation of the potent lolitrems A and B from pastures where ryegrass staggers had occurred in New Zealand.

Bourke et al (1992) reported a staggers-like syndrome in cattle in New SouthWales and attempted to distinguish the signs from those of ergotism. The authors maintained that ruminants with the nervous syndrome of ergotism exhibit tremors and do not show the convulsive signs described by earlier authors. Fink-Gremmels and Blom (1994) reported the existence of the staggers syndrome in the Netherlands during the dry summer of 1991. This was seen in sheep as well as cattle and also affected a few horses grazing ryegrass pastures or fed hay made from this grass. Up to 60% morbidity was seen but there was no mortality. Clinical signs however persisted for six weeks after exposure to the source had ceased. Examination of hay samples for the presence of lolitrem B were positive for the first time in Europe and the endophyte *Acremonium lolii* was demonstrated in infected grass seed imported into the country from New Zealand. Pritchard and Lewis (1995) commented on surveillance reports of the VIS describing extensive outbreaks of ryegrass staggers in England and Wales in 1995. The authors considered that most commercial ryegrass seed present in the UK was largely endophyte-free but that the infection was common and widespread in long established permanent pastures, even when ryegrass was a minor component. Farmers in New Zealand consider that endophyte-infested seeds offer some protection against insect pests.

2. *BOTULISM*

Botulism is an ancient and much feared disease of both mammals and birds. It is caused by the botulinum toxin which is produced under certain circumstances by the spore forming and obligatory anaerobe, *Clostridium botulinum*. In mammals, the disease is characterised by a flaccid paralysis that commences in the hind limbs and which progresses to affect the muscles of respiration and eventual death.

C. botulinum is found in soil and mud where it exhibits a saprophytic association with vegetable matter. Massive outbreaks of botulism in water fowl in which thousands of birds succumb are recorded by lakes and rivers throughout the world.

Blandford et al (1969) working at Sutton Bonington VIC reported the occurrence of botulism caused by *C. botulinum* type C in wild duck on a river in Leicestershire in a hot summer. Ferrets were also poisoned when they were fed the duck carcasses. VIC workers investigated wild bird deaths on East Anglia during the same summer (Borland et al 1977). Later, Blandford and Roberts (1970) reported the first case of botulism as a cause of loss in intensively-farmed poultry, again due to type C *C. botulinum*. Intoxication was due to birds cannibalising decomposing carcasses of birds which had succumbed to the condition.

Subsequent investigations by members of the VIS established the presence of high numbers of spores of *C. botulinum* type C in poultry litter and also in carcasses taken from the floor of broiler houses (Roberts and Collings 1973; Smart et al 1983). This work established the possibility that such carcasses could contain toxin under the current systems of poultry farming.

According to Theiler et al (1927), the first description of bovine botulism in South Africa was by Le Vaillant and took place as early as the late eighteenth century. Theiler described the occurrence of "lamsiekte", a disease of cattle which was known to be caused by eating carrion. In this region of South Africa, cattle searched extensively for bones and carrion because of the naturally occurring and extensive aphosphorosis of the soils and of the vegetation. It is of particular interest that Theiler was able to reproduce botulism in cattle by feeding the animals the decomposing carcasses of native fowl. Bennetts (1933) reported that losses from botulism of sheep in Western Australia was responsible for greater economic loss than for all other diseases combined. The cause was thought to be the ingestion of carrion following a large increase in the rabbit population.

Bovine botulism outbreaks have been attributed to the ingestion of decomposing cat carcasses found in silage and hay (Prevot et al 1955; Fjolstad and Klund 1969; Berg et al 1975). Doutre (1967) reported botulism in both cattle and horses with access to drinking water from a well containing decomposing cat carcasses.

In the UK, bovine botulism had earlier been suspected by Clegg and Evans (1974) working from Sutton Bonington VIC. Appleyard and Mollinson (1985) claimed that poultry waste was a cause of an outbreak, but there was no proof that the disease was indeed botulism, nor that the waste contained either the toxin or the spores of *C. botulinum.*

Clegg et al (1985) working from Sutton Bonington VIC reported the first confirmed case of bovine botulism in the UK and demonstrated exceptionally high levels of toxin in the dried musculature of the poultry carcasses found in the poultry litter. The litter had been scattered on the pasture as a form of manurial treatment and the cattle had been seen to consume these carcasses. Illness had also occurred in local dogs which were seen scavenging in the same field. Gibson (1986) of the VIS described an outbreak of botulism in a dairy herd. McLoughlin et al (1988) reported a major outbreak of botulism when 80 out of a group of 150 beef cattle fed ensiled poultry litter in Northern Ireland where this practice was said to be not uncommon. Sixty-eight animals died. Type C *C. botulinum* toxin was demonstrated in samples of decomposed poultry carcasses present in the litter and the authors state that feeding of ensiled poultry litter in this way entails serious risks.

The reason for the eventual successful demonstration of botulinum toxin by Clegg et al (1985) in the blood of affected animals is of interest as it was the smaller animals which were affected. The highest value of toxin found in these animals weighing 300-400 kg was 50 MLD/ ml. The volume of blood in a 500 kg a yearling would be 27 l and this would mean that the total amount of toxin circulating was 900,000 MLD (Smart et al 1987). It was considered that this amount of toxin could be extracted from 36 g of chicken carrion and that this weight of decomposing carcasses could have been ingested by animals of this size.

McLoughlin et al (1988) found toxin to be present in poultry carcasses at levels of 28.4, 15.8, and 1673 MLD/ g of sample. The highest level of circulating toxin was found to be 354.8 MLD/ ml serum. The weight of the 5 month old beef cattle was not given. However the levels of toxin ingested must have been considerably greater than in the case described by Clegg et al (1985) although the poultry source contained lower levels of toxin. Animals would have had to consume over ten times the amount of carrion, to produce the highest circulating value found by McLoughlin et al (1988). The possibility of *in vivo* toxin production has been frequently considered by authors - such as Minervin (1967) - but in the case described by Clegg et al (1985), a search for toxin in the contents of the rumen, abomasum, small intestine, caecum and colon proved negative, although *C. botulinum* type C was isolated from these sites.

Smart et al (1987) added further findings to the report of Clegg et al (1985) and discussed the implications of this diagnosis. The authors recommended the safe disposal of all carcasses and the need for a generally improved sense of hygiene in pasture management. This was considered to be necessary to avoid the distribution of spores of *C. botulinum* even more widely into the farming environment.

Plans were being made to extend the use of ensiled poultry manure as a cattle feed on a commercial basis but now these did not proceed. Later, the occurrence of botulism in horses was reported following the feeding of badly-made big bale silage (Ricketts and Greet 1984). This finding together, with the report of major losses by McLoughlin et al (1988) reinforced the view that botulism should be considered as a possible sequel when any changes in methods of fodder preservation were planned.

Earlier, workers at Sutton Bonington VIC had been amongst the first to associate ovine listeriosis with the feeding of contaminated silage (Clegg et al 1965). A disregard for hygiene in the methods of handling of bulk fodder remained a feature on many farms in the EMR however. The introduction of big bale silage after the mid-1970's resulted in some improvement of slovenly practice.

In view of the fact that botulism of man due to type C or type D toxin, is most infrequent, a recent report that the first case of infant botulism in Japan was diagnosed as being caused by *C. botulinum* type C for although the majority of infant botulism cases have been caused by types A and B (Ogoma et al 1990), the possibility of C.*botulinum* type C infant botulism should be entertained. Gilbert,R J (personal communication 1996) however does not consider the evidence incriminating type C poisoning to be convincing. Roberts and Gibson (1979) maintained that type C toxin appeared to pose no additional problems to the food industry and that measures taken to inactivate or control the other types of *C. botulinum* should also control type C. The authors made severe strictures about the confirmation of a diagnosis of human type C intoxication in the cases described in the literature. However, if further outbreaks of type C *C. botulinum* infection were to be found in broiler flocks, difficult decisions would have to be taken under the provisions of the Food and Environment Protection Act 1985.

3. *BRASSICAE CROPS AND THEIR ASSOCIATED TOXICOLOGY*

i. INTRODUCTION

Brassica fodder has proved to be an invaluable winter feed as they are a plentiful source of protein for ruminants. The selection of varieties, the methods of cultivation and the harvesting and feeding have proved to be significant steps in the history of practical animal husbandry.

High yielding varieties of these palatable crops have been bred as have frost- resistant varieties to allow use throughout the winter from September to March. Sowing in narrowly spaced drills and the replacement of grazing by forage harvesting, were both notable improvements in the management of the crop. Later, advances in weed control removed the need to use *Brassicae* sp crops in set rotations.

The first introduction of *Brassicae* species from the native Mediterranean took place in the 17 th century. Initial studies of the different species were made only recently (U Nagaharu 1934). At this time, the kales were included with cabbages and kohl rabis as varieties of *Brassicae oleracea* L. Thousand head kale was designated var *fructiosa*, and marrowstem kale as var *acephela*. Overall, the extensive exploitation of these crops has proved to be safe and there have been few serious animal health problems resulting from their use. The risk of toxicity has been further reduced by skilful breeding and instruction on safe levels of feeding.

The scale of the use of *Brassicae* sp crops is given by the Annual Abstracts of Statistics collected by the Rowett Research Institute (Wainman et al 1984). These show the acreage on which rape, kale, cabbage, savoy and kohl rabi were grown in the years 1971 to 1981, together with the calculated yields. The yields of kale increased until 1977 but after a fall in 1979, the acreage has declined. This reduction was probably because of the introduction of improved methods of making and handling grass silage. No recent statistics have been collected on the acreage of kale planted.

Cabbage *(Brassica oleracea* var *capitata*) was once a commonly fed plant but its popularity fell with the introduction of new kale varieties and the older large drumhead cabbages are no longer grown for cattle.

An important development in the safe use of *Brassicae* sp fodder was the demonstration of the toxic factors present. The isolation and the determination of the levels of the toxic principle S-methyl cysteine sulphoxide (SMCO) was accomplished in 1973 by workers at the Rowett Institute (Smith 1980). Recommendations on the levels of feeding of specific crops of kale were made by Sutton Bonington VIC in collaboration with the Nutrition Chemists of ADAS. After several winters, this advice was no longer required, probably as the result of sowing of new varieties with reduced SMCO levels.

The two disease conditions associated with the feeding of *Brassicae* sp crops are goitre and a haemolytic anaemia.

ii. HAEMOLYTIC ANAEMIA OF RUMINANTS

Anaemia of cattle associated with the feeding of kale was first described by Rosenberger (1939). The considerable dependence on this crop in Germany during the second world war was because protein cake was no longer imported. Kale poisoning caused considerable losses in German dairy herds (Rosenberger, G - personal communication).

The condition was described in detail in the UK by Sutton Bonington VIC (Clegg and Evans (1962) and later by Penny et al (1964). Earlier Evans, (1951) had reported the deaths of 11 out of 12 cows fed on kale. Stamp and Stewart (1953) gave a description of anaemia in sheep fed on rape. The condition had been reported elsewhere by Coté (1944) in Canada, Schubert (1954) in Germany and by Rebesko (1958) in Jugoslavia.

Clegg and Evans (1962) also included descriptions of anaemia occurring in cattle which had been fed drumhead cabbage (*Brassica oleracea* var *capitata*) and also Brussels sprouts (*Brassica oleracea* var *gemmifera*).

All ruminants appear to be susceptible to this haemolytic factor. Greenhalgh et al (1969) considered that cattle and goats are more susceptible than sheep. All the Brassicae sp forage crops contain levels of the compound S-methyl-cysteine sulphoxide (SMCO) which produces haemolysis in vitro and which can affect the welfare and productivity of the entire herd or flock and result in death.

The first and most notable sign of SMCO poisoning is the occurrence of Heinz-Ehrlich bodies. These bodies were first described in cattle by Penny et al (1961). They normally constitute some 0.04% of the total erythrocyte count. Levels as high as 20% Heinz-Ehrlich bodies and total erythrocyte counts as low as 1 million per cu mm were found in severely affected cows in cases of the macrocytic-hypochromic anaemia found in kale poisoning (Clegg 1966). The normal erythrocyte count in cattle is 7.0×10^{12} l (range 5.0 - 9.0)(Archer and Jeffcott 1975).

Arbitrary recommendations were made by some workers, for example that the amount of kale should be reduced if the percentage of Heinz-Ehrlich bodies should rise above 0.3% (Wainman et al 1984).

Clegg and Evans (1962) described the death of five animals in a herd of 70 dairy cows, the poverty and weakness of half the survivors, the later intractable infertility and the slaughter of the entire herd six months later. In every case, the clinical signs were similar and followed the occurrence of Heinz-Ehrlich bodies and a rapid fall in haemoglobin concentrations. Affected animals showed haemoglobinuria, "saucer white" pallor of mucous membranes, tumultuous heart sounds described as "drum beat", later jaundice of the skin of the udder and mucous membranes, weakness, inappetance and death. Fig 45 shows the jaundiced and enlarged golden-coloured liver and paleness of the heart of a six-year-old cow. The kidneys were dark and chocolate coloured. The maintenance of high milk yields by these weak cows continued until the point of collapse. Survivors exhibited anoestrus for at least three months after calving.

It is probable that some degree of haemolytic anaemia occurs with any substantial feeding of this fodder to ruminants (Clegg 1966). This may result in slight transient haemoglobinuria which may remain undetected. Greenhalgh et al (1971) found that overt anaemia occurred in only 6.4% of the cows at risk during a survey of herds where kale supplied one third of the total dry matter intake. However, 36% of the cows showed appreciable Heinz-Ehrlich counts. Penny et al (1964) claimed that rabbits fed on kale ad lib for 6 weeks developed anaemia. Clegg and Evans (1962) were unable to reproduce this finding when they fed rabbits the kale which had proved to be poisonous to cows. Rosenberger (1943) failed to produce the condition in either rabbits, mice or guinea pigs and it is generally accepted that small non-ruminants are not susceptible to poisoning by SMCO. Greenhalgh et al (1969) gave an account of a rhinoceros at London Zoo said to exhibit haemoglobinuria after feeding on cabbage.

iii. GOITRE AND OTHER CONDITIONS

Brassicae sp crops have been known to contain goitrogenic substances since they were first used. Chesney et al (1928) fed rabbits on cabbage and observed the development of a goitre. Two thioglucoside goitrogens are present and these act in different ways. Thiocyanate inhibits the uptake of iodine by the thyroid and this effect can be overcome by increasing iodine.

Goitrin belongs to the thiouracil group of goitrogens which affects the synthesis of thyroid and the changes are not reversed by supplying extra iodine.

The possibility that low levels of both goitrogens could be present in the milk of cows fed on kale and that this in turn could prove goitrogenic to children drinking was suggested by Clements and Wishart (1956). Subsequent work showed that they occurred in such low concentrations but that the risk could be discounted (Virtanen et al 1963). Johnston and Jones (1966) found variations of the goitrogens in different plants but did not consider it worthwhile to breed varieties with reduced thiocyanate content, as the action was moderated by the addition of extra iodine.

The effects of goitrogens in animals are not widely reported. Russel (1967) described a mild goitre in lambs fed kale which were otherwise unaffected and which was alleviated by iodine supplementation.

Workers at Sutton Bonington also established the first case of nitrate/nitrite poisoning in cattle in the UK following the 1976 drought. This outbreak followed the feeding of fodder with high levels of nitrate (Jones and Jones 1977; Jones 1988). Nine heifers in a group of 69 died and five aborted. High levels of nitrification had taken place in the soil during the hot summer and little leaching had occurred in the subsequent drought. The authors also described the use of high levels of sewage sludge in 1974 and the dangerous nitrate levels demonstrated in the hay and straw which had been fed. Jones (1982) working from Sutton Bonington later reported the suspected poisoning of cattle with an ammonium nitrate fertiliser. Raised nitrate levels in plants of the *Brassicae* sp. were associated with weather conditions and were reported elsewhere by the VIS. Cawley et al (1977) reported heavy applications of a nitrogenous fertiliser to a kale crop before the drought and the rapid growth of the crop following the heavy rainfall in September. Mortality in cows followed feeding of this crop and the abortion of seventeen cows in a herd of one hundred was reported.

Nitrate poisoning in cattle fed turnip tops and roots was reported in New Zealand by Dodd and Coup (1957). Greenhalgh (1971) considered that although nitrate ion concentrations in Brassicae sp crops could be as high as 5% in foliage and 3% in roots, these levels do not prove toxic because they are accompanied by high levels of soluble carbohydrates.

Dairy cow infertility has been associated with kale feeding (Boyd and Reed 1961). These workers indicated that farms with greater acreage of kale crops exhibited higher levels of infertility. However, Melrose and Brown (1962) reported that kale-fed heifers exhibited a longer period of dioestrus than did heifers fed on hay. Williams et al (1965) reported that a flock of ewes fed kale exhibited shorter periods of oestrus than the control ewes.

There must always be vigilance when feeding this fodder. New varieties have been selected with low SMCO levels - and the limits of the amount to be given established. The temptation to overfeed a luxuriant crop must be avoided particularly when harvesting a crop within a set period to feed a dairy herd.

Discussion

This chapter describes the course of those investigations which involved national enquiries. In these cases, the value of the VIS was the ability to collaborate with both national organisations and international workers. The results not only solved agricultural problems but were also part of advances which were taking place across the fields of biology and medicine.

The role of the VIS in the international enquiries into aflatoxicosis was a model of such work. The flexibility and freedom allowed in the carrying out of investigations meant that they could be initiated quickly and with the certain and ready support of other departments of CVL and other MAFF laboratories. VIS workers described the course of the outbreaks as the more toxic meal was found first in turkey, then poultry, pig and finally cattle rations. The number and the value of the publications describing field outbreaks and research findings constitute a valuable record of the progress of the investigation by colleagues in the VIS and CVL. Toxicity trials carried out at VIC's using laboratory animals

also gave early warning of the danger of the first batches of groundnut meal suspected to be toxic. The possible risks to humans was considered to be of considerable importance in these enquiries. The effective liaison which was established with the feed industry lead to the publication by the Commercial Research Group in 1964 (A Commercial Research Group (Aflatoxicosis) 1964).

A criticism of these VIS investigations is that there was only one enquiry into the effects of aflatoxin on immunogenesis in the field. The foresight of the investigators in this case was commendable (Siller and Ostler 1961). The recognition of ryegrass staggers affecting sheep in the UK proved to be a matter of interest to research workers in New Zealand and the USA. Although the condition was of interest as a clinical entity, the disease has not been considered an important cause of loss in the UK. Work on tremorgenic toxins was to continue and the climatic conditions allowing the growth of the fungus were found. In the antipodes, measures are taken to prevent access to such dangerous fields and warnings are given at times of risk. In the UK, the condition is now well-recognised and it occurred during the drought of 1995 (Pritchard and Lewis 1995).

The finding of botulism in wild duck and later in poultry (Blandford et al 1969 and Blandford and Roberts 1970) was followed by reports of the condition in turkeys and by the successful search to confirm bovine botulism as a diagnosis in the UK. The enquiries into botulism have remained matters of public health concern and to continuing close liaison with the PHLS. The later diagnosis of botulism in horses (Ricketts and Greet 1984) increased the awareness of the potential dangers from botulism in the UK and the need for improvement in the hygienic management of pastures.

The confirmation of a diagnosis of bovine botulism in the UK caused concern. Plans for the ensilage of poultry manure as a cattle feed fell into abeyance and better counsels prevailed about this unwise practice. Representatives of the feedstuff industry met regularly with VIS members and representative practising veterinary surgeons from each region of the UK. The forum also included the BVA (British Veterinary Association), United Kingdom Animal Trade Supply Association (UKASTA) and ADAS and proved of value for the exchange of information in toxicological enquiries.

The investigations into the risks from kale and other *Brassicae* sp crops were instituted at the time of the occurrence of serious losses and both publication and liaison which followed were successful. There was no lasting concern about human risks and the awareness of the problems was important to stock owners and to plant breeders. The enquiry was successful because of the practical steps that were taken to avoid the excessive feeding of crops with dangerous levels of SMCO and by cultivating new varieties with low SMCO content. Serious economic losses were previously caused by kale poisoning of dairy herds and the high value of kale as a fodder crop had been questioned following publicity in the farming press (Clegg 1963).

The WIIS was set up in 1991 with the following aims:- (a) to advise farmers, gamekeepers and other land managers on the legal ways of controlling pests (b) to advise the public on how to report illegal poisoning incidents (c) to investigate incidents and to prosecute offenders. Meanwhile the Pesticides Safety Directorate (PSD) has been set up to direct campaigns against the illegal poisoning of animals and to publicise the WIIS. The efforts made by the Sutton Bonington VIC for the VIS to take the lead in the investigation of wild life losses has been accomplished.

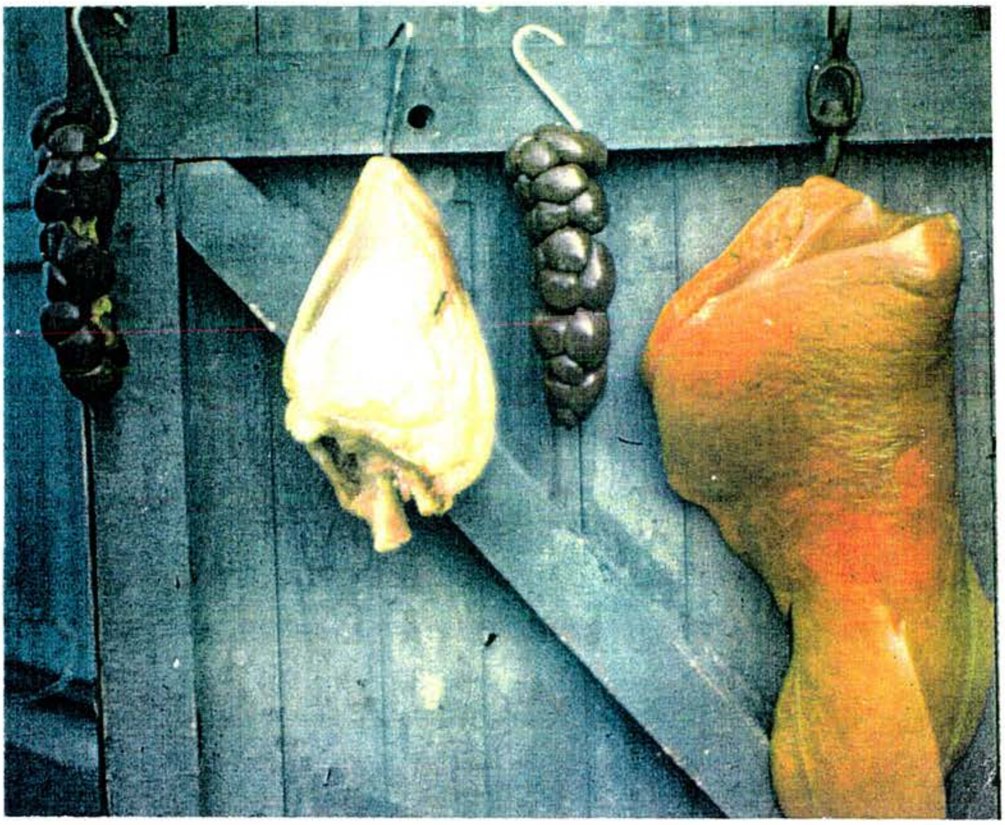

FIGURE 45 The viscera of a 6 year old cow showing the lesions of *Brassicae* sp. poisoning.

VII. DISCUSSION

The thesis has described the procedures taken by the Sutton Bonington VIC in the course of the investigation of toxicological problems. The VIO was required to enquire into the cause of animal disease in the EMR. Participation in national health schemes and a limited participation in trial work was also expected.

The following questions may be asked:-

1) How successful was the VIS in carrying out these enquiries during this period of change in agricultural practices?
2) What impact did the findings have? If the conclusions were properly publicised to fellow scientists and the public, did they influence the heightened awareness of the safety of food - and of environmental pollution?
3) What could the VIS offer in future of toxicology enquiries? What expertise or background will be called for?

Recently, the "James" report (Food standards Agency: Report by Professor P James 1997) has described the collapse of the public's confidence in the safety of food in the UK. There has been widespread support for the principles regarding the formation of a Foods Standards Agency. This followed consultation with consumer organisations, public health specialists, current and previous chairmen of scientific committees involved in public health, and food policy and the chief executives of government agencies. Many relevant organisations made interim submissions to this committee and the report found that there were specific fears about the chemical safety of food and listed veterinary drug residues, pesticides and heavy metals amongst these.

The "James" report found that the public were concerned by the long-term impact of chemicals, including mixtures, and the variation in the chronic, as well as acute, effects on different sectors of the public.

In a withering criticism of past organisation, the report found that the links were poor between the SVS, the Meat Hygiene Service (MHS), and the Veterinary Laboratory Agency (VLA) and those organisations responsible for monitoring human health and food safety.

The White Paper (Cm 3830) entitled 'A Force for Change' was presented to Parliament in January 1998. This paper gives a commitment by the Government to create a Foods Standards Agency and again describes the lack of co-ordination between the various government bodies involved in food safety. The "James" report lists three reasons for the present unsatisfactory state of affairs which have not been conducive to promoting national health or national wealth. Conflict has occurred between the promotion of the agricultural industry and the necessity to carry out effective enforcement to ensure public health. This has been especially so in the case of the monitoring carried out by the MHS and the organisation's efforts to protect human health. The report recommended the immediate separation of all aspects of food safety from MAFF including the making of policy, surveillance, control and audit. The other failure of co-ordination was the result of fragmentation of all the different bodies involved in food policy, and the monitoring and control of food safety. In particular, the links were poor between those involved in monitoring human health, the veterinarians within the SVS, the VLA and the MHS. There was no clear strategy for monitoring the surveillance of chemical food safety. The third failure of co-ordination was due to the unequal enforcement of food law throughout the UK.

The enquiries which followed the Lowermoor water poisoning incident indicated the deficiencies that existed in the preparedness of the health authorities (Baxter 1991; Mayon-White 1993). Indeed, Baxter stated that some parts of the emergency services in the UK were not ready to cope with such chemical accidents. There had also been little recognition of the risks of long-term chemical injury either carcinogenically or teratogenically, or of effects on target organs. Coggon (1991 and 1995) criticised the two reports produced by the independent group (Lowermoor incident Health Advisory Group 1989 and 1990).

Public concern remained and there existed a self-selected group of patients with heightened anxiety and awareness. The limited response of veterinary workers to this accident was delayed and largely theoretical (Allen and Sanson 1989).

Although it is undecided whether the FSA will have a role in future water poisoning incidents, a great deal may be learned from the inadequate, delayed response to this occurrence by both the medical and veterinary authorities.

THE PAST

It is necessary to remember what the general public view of toxicological hazards was at the beginning of these studies. Rachel Carson's book "*The Silent Spring*" was published in 1962 and drew attention to the deadly effects and happy-go-lucky use of chemical pesticides, herbicides and fungicides. The author (1907-1974), a scientist working in the United States of America's governmental Fisheries and Wildlife Service, understood the approaching problems. Elsewhere, she had written "As cruel a weapon as the cave man's club, the chemical barrage has been hurled against the fabric of life". The book caused a considerable stir in the United States and was subject to many discreditable ploys by the agribusiness community. The effect of the book on public opinion in the UK was less manifest. Even in 1964, major pollution incidents, such as the contamination of fields around Smarden in Kent by a fluoracetate compound, which required the removal of some 70,000 tons of soil and where the poison may have leaked to a depth of 18 feet (6m), attracted little national attention.

In 1969, the Reith lectures - entitled *"Wilderness and Plenty"* - were delivered by Sir Frank Fraser Darling (1903-1979). This internationally renowned ecologist had studied at the Midland Agricultural College, and was a member of the Royal Commission on Environmental Pollution from 1970 until 1973. These worthy lectures can be seen as the starting point of public concern and the beginning of the acceptance of the importance of ecology and of impending risks to the environment.

A Royal Commission on Environmental Pollution was appointed under the chairmanship of Sir Eric Ashby and produced its first report in February 1971. This deliberated on the need to weigh costs against benefits. The creation of the Department of the Environment followed later the same year. The magazine "The Ecologist" first appeared in 1970 and published the so-called "*Blueprint for Survival*" which was a scheme to get Britain into an ecologically sustainable condition. Increasingly, discussion was about birth control and exaggerated fears of population "explosions" with the consequent drain on world resources. The `Blueprint` was later attacked for its lack of scientific detachment.

The general public had little knowledge of toxicological problems, or of the possibility of environmental damage, in the early 1950's. Even at this stage, the damage to the environment was becoming apparent to more enlightened agriculturists although it was thought to be a solvable issue that could be repaired merely by more judicious use of agents and by controlling monopoly interests in agriculture and the agro-chemicals industry.

It is pertinent to enquire how much was known of the public health risks consequent upon farming practice - and particularly for those of the public living in the Derbyshire ore field - and why there were so few records of medical and veterinary investigations. Concern about human health in this region occurred only later. A survey being carried out by paediatric workers from St Mary's Hospital Medical School, London was instrumental in the discovery of children with high blood lead concentrations, from around a smelter site near Matlock in 1972 (Appendix D).

There had been national concern about pollution near several lead industrial sites situated throughout the UK, including those at Northwich, Cheshire, the site of Octel the petrol additive manufacturer (1971), Rio Tinto smelter at Avonmouth (1972), the Isle of Dogs smelter (1971), North Ferriby Capper Pass smelter in Lincolnshire (March 1972) and latterly, the large secondary smelting site of H J Enthoven at Matlock, Derbyshire. The Rio Tinto smelter at Avonmouth had been closed for two months from January 1971 because of the risk of lead poisoning to workers at the plant. This had been the subject of editorial comment at national level reflecting a new public disquiet about raised lead blood concentrations and their possible medical consequences.

In 1971, the Central Unit for Environmental Pollution announced the commencement of the sampling of children in nine areas of the UK for evidence of lead poisoning, including those from around the smelter site at Matlock (Appendix E). The seriousness of contamination of the area around that smelter became local knowledge and the Sutton Bonington VIC was increasingly involved in the sampling of cattle and fodder on two farms lying to the north of it. In 1972, there was national concern about pollution surrounding lead smelters with descriptions of fodder contamination in the national press (Appendix F).

In the early 1950's, there was no knowledge of the scale and severity of lamb losses that were occurring due to lead poisoning. The clinical condition was not recognised or described. The one description of crippled lambs was neglected (Gardner 1924). Also, the authoritative authors on lead poisoning, Allcroft and Blaxter (1950) did not consider that plumbism was a danger to sheep in Derbyshire. Allcroft (1950) stated that lead poisoning would not occur in sheep grazing on lead rakes. It was calculated that there was an estimated daily intake of 50 mg Pb by each ewe and concluded that very little absorption of the metal occurred. Later, Stewart and Allcroft (1956) were to describe lameness and poverty in older lambs in a small and localised lead mining area in the northern Pennines. Publicity in 1972 alerted farmers to the condition and stressed its crippling nature (Appendix G).

The stories passed by word of mouth of *bellanded* pastures described certain fields as being dangerous principally to horses grazing there. The risk to grazing cattle was not appreciated by the farming community or indeed by the veterinary practices in north Derbyshire. Archaeological sites of smelting and lead manufacture were no longer remembered. Animals were housed in extensively contaminated 17th century buildings where smelting had taken place and in some animal housing ancient deposits of lead rich fume could be found on the stone walls with values of up to 11,640 ppm/DM Pb (Annual Report 1968 Sutton Bonington VIC). Local names such as Cupola Farm had been effaced. Urban families bought old buildings in the country and were horrified to learn later of the extent of heavy metal contamination of the site. In several cases, such a discovery was to follow the diagnosis of lead poisoning in recently acquired ponies.

Lead poisoning in swans had been neglected for many years. Published data on mortality rates in these birds was being collected (Bacon 1980, Coleman and Minton 1980). The public attitude to wild life losses had been less excitable in the 1960's and many carcasses of swans had been known to be found floating in the Trent and its locks and local officers of the Royal Society for the Prevention of Cruelty to Animals made early enquiries (Burgess 1981). It was not until the observations made by the Sutton Bonington VIC (Simpson et al 1979) on the large swan herd living on the embankment steps of the Trent in the town of Nottingham, that there was a realisation of the cause of this extensively occurring mortality. The extent of lead poisoning was well documented and the main problem shown to be due to the ingestion of lead split-shot and ledger weights used in coarse angling during the fishing season (Birkhead 1982 and 1983, Sears 1988).

At the beginning of this study, there was little or no understanding of the scale and significance of the losses of birds which had occurred in the eastern half of the UK in the 1960`s. Public awareness of the risk to bird species increased considerably however. In 1997, the UK's leading non-governmental bird conservation organisations - the Game Conservancy Trust, the British

Trust for Ornithology, the Royal Society for the Protection of Birds, the National Trust and others - joined together to discuss priorities for bird conservation. This approach followed the one developed by the Government's Steering Group on biodiversity.

The investigation into the deaths of wild birds by PTFE took place in the 1970's. Initially, the possibility that poisoning could occur under such extensive conditions out-of-doors was met with disbelief by the company chemist - a worker of international standing. However, the previous experience of the Sutton Bonington VIC of the pathology of this poisoning, the concern about the adjacent school and the scale of the deaths, together with a heightened perception shown by the local community to environmental dangers, ensured the successful conclusion of the investigation (Blandford et al 1975).

The study of the uptake of I **125** by swans proved to be an early model of the use of radio-nuclides in environmental waterway investigations (Howe and Bowlt 1992).

In the case of copper poisoning of sheep, at the beginning of this study, there was no recognition that this was other than an occasional hazard resulting from the careless use of copper preparations. Many outbreaks could well have been misdiagnosed. Future plans for the housing and dry feeding of sheep were complicated by the practical difficulties of reducing the copper levels found in feed components and the inaccuracy of their published copper values.

In the case of fluorosis, a history of successful veterinary investigation was already in existence. The first descriptions of bone lesions in cattle due to fluorosis were made in India. As early as 1932, Mahajan (1932) had observed an osteomalacia of cattle in southern India. Shortt et al (1937) described fluorosis affecting man in the state of Madras, where Vishwanathan (1934) had previously observed so called rheumatoid arthritis of cattle. Shortt submitted bones and teeth from this area to the Indian Veterinary Research Institute (IVRI) at Izatnagar where high fluorine values were found (Sen 1957). Majumdar and Ray (1946) produced a fluorosis map of India. This pioneering joint medical and veterinary investigation stands as an example of how to approach toxicological problems. Later, the monitoring of wild life would be used to estimate the scale of industrial pollution (Hell et al 1995).

The importance of the other industrial toxicities, including molybdenosis and the elements found in pulverised fuel ash, had not been observed in the EMR before. The disposal of pulverised fuel ash was a new project and farmers were found to be prepared to take part in trials with the Central Electricity Generating Board on their own land, recognising that the board had a problem. This co-operation reflected the current attitude of farmers which was one of active collaboration with ADAS. ADAS Livestock Services published a valuable report entitled "Herbage composition and animal performance. Ash disposal site Barlow" (1986). As in earlier trials, the herbage grown on reclaimed sites, was considered to be safe for sheep and cattle although elevated plant levels of molybdenum, sulphur and selenium were demonstrated. Lambs became hypocupraemic and recommendations were made for their supplementation with copper.

Molybdenosis remained a localised problem in the EMR until a further outbreak occurred downwind from a petrol refinery near Southampton in the UK (Gardener and Hall-Patch 1968).

In the UK, knowledge of animal mycotoxicoses was abysmal in the early 1950's, despite descriptions of classic human and animal outbreaks in both Asia and America. There was no recognition of animal disease, other than that of ergotism (Edwards 1953) and a condition known as "migram" apparently restricted to salt marshes in Kent (Chesney 1953). The repeated poisoning of laboratory guinea pigs by aflatoxin present in commercial feed was to remain undiagnosed until 1966 (Butler 1966). This was despite the necessary close scrutiny of the management of affected colonies and the availability of descriptions of the pathology.

Brassicae sp poisoning of ruminants had been described in the 1950`s (Evans 1951: Stamp and Stewart 1953)). Despite the descriptions of the severity of loss suffered by cattle in Germany (Rosenberger 1943), the disease was not characterised in the UK until the early 1960`s (Clegg and Evans 1962). The concept of the poisoning of an entire dairy herd by a fodder crop, proved to be a surprise to agriculturists at that time (Clegg 1963).

PROGRESS

Having considered the past state of knowledge, the next step is to assess what effect the findings of the Sutton Bonington VIC had on any remedial measures and perhaps on future veterinary and agricultural practices.

The impact of the investigations by Sutton Bonington VIC into lead poisoning of animals was considerable and can be seen to have provided the key information for the ensuing veterinary, medical, agricultural and planning decisions.

Interest and speculation concerning the role of heavy metals, especially lead, as carcinogens and their role as a cause of numerous novel forms of human illness continued. A case for the involvement of lead in the aetiology of disseminated sclerosis of man has been made (Warren et al 1967) but multi-element surveys have not confirmed a geochemical link (Ward et al 1985). More recently, Gerhardsson et al (1995) studied mortality and cancer in lead smelter workers and concluded that the increased risks for stomach, lung and bladder cancer keeps the possibility of human carcinogenicity open. The implications of lead poisoning of past and present populations in immediate and long-term health problems remain a question of supreme importance in public health studies (Landrigan 1991).

Daily communication with the veterinary practices in the area of the ore field allowed early exchange of information. Neighbouring practices were aware that lamb deaths were commencing. Such exchange of information often accompanied enquiries by the VIO about the occurrence of "swayback" in the territory of a particular practice. Lead poisoning occurred on farms well outside the area of the ore field, sometimes following the purchase of contaminated fodder from farms lying close to the site of the smelter. A general awareness of the possibility of lead poisoning affecting grazing and housed stock commenced in these first years. Even so, farmers had often already made excavations for silage pits into spoil heaps and sometimes into unknown lead-bearing lodes.

Communication with the farming community at this time did not suppress an enthusiasm for digging and road making. However, later in the 1970`s, when the seriousness of the poisoning of dairy herds became known, the speed of communication within the farming community was remarkable. Publicity given to the importance of reducing the soil content of silage was promoted at an ADAS farm demonstration. Appendix G is an example of an article written for the farming press. Such ADAS publications were posted to every stock farmer in each of the five counties of the EMR. Occasional local radio programmes covered topics of immediate interest such as the annual "swayback" forecasts.

The most consistent extension work was carried out by means of the Veterinary Study Groups. In the 1964 Annual Review of Prices and Determination of Price Guarantees, the Minister of Agriculture announced the setting up of the Central Veterinary Study Group to promulgate results of veterinary research and their applications to the farming community. Representatives of the national farmers' unions, the Agricultural Research Council, the British Veterinary Association and MAFF attended the first meeting. By the time of the second meeting, the organisation had mushroomed with plans to form both Regional and Local Study Groups. The Regional Veterinary Officer of the EMR became chairman and local study groups were created on a county basis with the Divisional Veterinary Officer in the chair. Numerous regular meetings were convened and in addition to the continuing national problems of bovine mastitis and lameness, local problems were raised. In the Derbyshire Study Group meetings, lamb losses were often discussed and the VIO learned of further occurrences of "swayback" and lead poisoning. The speaker at these small evening meetings held in public houses was frequently the VIO, and there were opportunities to talk to shepherds about ewe nutrition and the administration of copper to prevent "swayback" of lambs. The effort made to support a full programme was considered to be worth while. These tripartite gatherings - farmers, practising veterinary surgeons and ADAS nutrition and livestock advisers - were the first occasion for them to meet and to learn of each other's work.

The range of audience reached by the VIO was wide as was the attempted coverage. The publications include those used in local extension work in various bulletins and the monthly reports abstracted in the weekly publication the *Veterinary Record*.

Scientific papers were published in specialised journals and papers were given at scientific gatherings. The VIO directed that the early publication of toxicological cases were to be a priority of the work of Sutton Bonington VIC.

Communications within MAFF ensured the distribution of reprints of scientific papers to all other VIC's. Requests for reprints were sent to fellow scientists throughout the world. Reports of the work of ADAS colleagues in related fields were also exchanged. Nutrition, dairy and livestock husbandry officers participated in joint planning meetings and together reported the results of trials. The successful liaison with other MAFF workers in toxicological enquiries has been described in the investigation of lead pollution of pastures and in the investigation of wildlife losses.

Communication with senior veterinary officers of the SVS and administrators within MAFF, took place and was facilitated by the use of an internal guide to the structure and to the functions of each of its component Divisions. Liaison with public health groups was effective as in the case of enquiries into zoonoses such as salmonellosis and psittacosis but assessment of the risks of chemical poisonings to humans was never satisfactory until implementation of the Food and Environment Protection Act 1985. When the Community Physician was informed of herd poisonings and was aware of the tissue and milk levels being found in an investigation, the officer was uncertain about the procedures to be taken and of the scale of notification that were to be made.

The success of the investigations carried out by Sutton Bonington VIC into the mortality of swans (*Cygnus olor*) was considerable. The Nature Conservancy Council's Working Group published their report in 1981 (Nature Conservancy Council 1981). This encouraged the development of non-toxic weights and recommended the phasing out of lead weights. The first alternatives were marketed in 1984 and a wide range of different products was soon available. A voluntary ban on the use of lead was introduced in 1984 but proved to be ineffective. Legislation in the form of the Control of Pollution (Angler's Lead Weights) Regulations (1986) was introduced and from 1987, it has been illegal to sell or import lead weights for fishing of over 0.06 g (Number 8 split-shot) up to and including 28.36 g (1 ounce ledger weights). These measures have met with success and Sears (1988) has reported substantial reductions in the incidence of lead poisoning of swans on the Thames. Sears (1988) considers that despite this improvement, the problem is unlikely to disappear as lead weights are still accessible. The number ingested should decrease further with time, as old weights sink out of reach and any illegal use of lead diminishes as stocks are used up. The Sutton Bonington VIC took a full part in the description of the investigation, including the pathology, carrying out the analyses, the remedial measures and the assessment of the recovery of the swan populations.

Increasingly the analysis of tissue levels of wild-life species is being employed to survey possible polluted regions (Langgemach et al 1995; Medevdev 1995; Craste and Burgatsacaze 1995). Hunting trophies have been used as indicators of historic lead pollution (Tataruch 1995).

Copper toxicity in sheep continues to be a cause of unnecessary loss. Studies of the breeds showed that several were extremely susceptible and that under certain conditions, they would succumb on pastures with normal copper herbage values (Whitaker 1997; MacPherson et al 1997). Suttle (1998) warned of the risk of "swayback" in the spring of 1998 following the mildest winter for eight years. A protocol for the injection of new-born lambs with copper is drawn up. The belief that swayback lesions were irreversible was challenged by studies at CVL and at the Moredun Institute in the 1970's. These trials indicated that dosing one member of a pair of twin lambs would allow normal development even though its partner slaughtered at birth had lesions, which almost certainly would have resulted in clinical disease. The risks of poisoning remain and the measurement of the dose of only 0.2 ml must be precise.

In the case of aflatoxicosis, the unfolding of the progress of the poisoning, first in turkey poults and then in other farm species, resulted in the control of shipments of dangerous meals and hence control of the outbreak. The rapid publication of the outcome of the investigations in the field, of laboratory trials, the liaison of pathologists, bio-chemists and the feed trades resulted in the taking of effective measures. Urgency had been added to all this work by the finding of the carcinogenic properties of aflatoxin (Lancaster et al 1961) and fears of a toxin in the milk of cows known to have consumed contaminated meal.

THE FUTURE

The VIS is judged to have made an impact on the progress of veterinary science and practice in the UK. Timely publications have been successful in reporting findings to both to the scientific world and to the farming public.

Collaboration with scientists from other disciplines have helped national and local liaison in many fields. The build-up of the picture of the seriousness and extent of the lead pollution necessitated government action to reduce levels in human food and the scale of losses in grazing animals and swans.

In 1998, the future structure of the VIS is once again uncertain and it will probably report to the new Food Standards Agency. The principal aim of the VIS is given as support of the SVS.

This support has been afforded by:-

1. Protecting the public by promoting food safety and taking action against diseases with implications for human health.
2. Improving the economic performance of the agriculture and food industries by taking action against diseases with implications for human health.
3. Protecting farm animals by high welfare standards.

To meet these aims in the future, the VIS will promote food safety, protect public health and improve animal health by providing diagnostic and analytical services. There is no mention of toxicological expertise and neither does this limited outline make reference to the involvement of the VIS in environmental questions and the investigation of wildlife morbidity. The past has shown that VIO's have taken an important part in environmental enquiries in their regions. They have been instrumental in decision making with consequences for animal health and for land use.

However, the White Paper (A Force for Change 1998) envisages that the Agency will participate in the management of all food-related surveillance activities undertaken by the Government and other bodies and will be able to initiate their own surveillance if they should identify gaps in the overall programme. Further, a joint Agency/Agriculture Department Committee will be established to co-ordinate the surveillance programme of other interested bodies, including the PHLS. The committee will be of little value unless it has regular disease intelligence of outbreaks and trends directly from the VIS without the complication of intermediaries.

The recommendations of the "Lamming" committee, which reported in 1992, are to be implemented (Chapter 4.17). An independent committee will be constituted and named the Advisory Committee on Animal Feedingstuffs. Its membership would include experts in microbiology, toxicology, veterinary medicine, biotechnology and human health. It would also represent the interests of enforcement authorities and consumers. This recognition of the importance of animal feedingstuffs in the human food chain with implications for the safety and quality of food, can only be applauded. Representatives from the VIS must take an active role in any such future committee.

Further it is stated (Chapter 9.5) that a new joint MAFF/Department of Health Communication Unit is being created and that the Chief Medical Officer will have particular responsibility for this. An external adviser is in the process of being appointed. Again, there must be immediate access to disease intelligence emanating from the VIS.

In the plans to improve food hygiene (Chapter 4.36), the Food Standards Agency (FSA) will initiate any legislative action which might be required to protect public health, for example in promoting the use of Hazard Analysis and Critical Control Points (HACCP).

The announcement by the Chief Executive describes the restructuring of the Veterinary Laboratory Agency (VLA) due to commence on April 1 1998. It describes the splitting of the organisation into Surveillance, Research and Laboratory Services. Surveillance is defined 'as the activity which collects, collates and interprets and disseminates information on animal disease and welfare and the implications for public health'.

The Chief Executive (Little 1998) states that the VLA cannot rely solely on material delivered to the VIC's to provide all the answers and there is a need to know that sufficient coverage exists. To this end, the VLA will introduce more rigorous ways of working by designing more careful surveys and by structuring information collection and epidemiological techniques. It is considered that this can best be done by greater emphasis on project work.

Criticism of this reliance on project work has been voiced (Luxton 1998). If there is to be a reduction in the present level of essential *ad hoc* surveillance of diseases of unknown aetiology, it is feared that potentially serious diseases may be missed, or their identification delayed, with disastrous effects on British agriculture, or more alarmingly, on the general public. Criticism of the principal of charging the owner for diagnostic work has also been voiced recently. Twenty-five years ago, Field (1972) considered that any check in the investigation of individual poisoning cases could result in delays whilst meat and milk products were in process of being consumed.

Future VIO's will be presented with environmental problems at a time when the public will be highly informed about local and national disasters. The future VIO will require knowledge of the region - the agriculture, its industries, geochemistry and the natural history. In addition, the VIO will be required to possess clinical skill. The role of a VIO must be more than the direction of a laboratory carrying out routine surveillance. Investigation requires a readiness to consider unknown entities and unremitting endeavour to solve problems.

APPENDIX A

References:- 1. Leigh (1700)

2. Farey (1811)

1. **Leigh, C (1700)** Oxford

Natural History of Lancashire, Cheshire and the Peak in Derbyshire.

But let us consider further the poysonous sulphure of lead, which will be better understood by the tragical and various effects which it produces, not only upon Human Kind but also upon Quadrupeds.

...why may not this sulphure then enter the very Penetralia of the nerves, and in those by its saline Particles produce a Corrugation, and by that means obstruct the Influence of such a proportion of spirits as are necessary to Nutrition! Hence the blood becomes dispirited, and performs not its due circulation but stagnates in various parts of the body: the serum becomes effete and Viscid, and hence proceed Hoarseness, Asthma, weakness and swelling of the joints.

This Distemper may be taken by working in the lead mine or by the fumes of the Ore smelting it: these very symptoms happen to Horses and other Cattle: these generally take the Distemper by feeding on the grass where the lead ore is washed, or by drinking of the water.

2. **Farey, J (1811)**

General view of the agriculture and minerals of Derbyshire; with observations on the means of their improvement.

Vol.1 Macmillan, London.

Buddling was little or scarcely at all practised till within the last 50 years, much of this has since prevailed to the vexation and annoyance of the farmers in numerous instances and indeed to every class of the inhabitants to a degree, by thickening and bellanding or poisoning if the Brooks and even the large River Derwent at the times when the buddlers left off their thick waters and buddle-sludge. I have myself seen every part of the River

Derwent at Matlock Bath, which was before beautifully clear and limpid, suddenly made as thick and yellow as a strong solution of Gumbouge and so to continue for hours from the Buddling operations of the miners about Wensley, 4 miles higher up the river; by which I was told the fish are entirely poisoned, or driven away in dry seasons.

I heard of such losses by the Farmers from the Bellanding or poisoning of their Cattle which drink the Brooks or Streams polluted by the Buddlers of old Hillocks and Wastes, that it is surprising nothing has been done to put a stop to the practice; except perhaps where performed on a small scale on regular Mine-hillocks for obtaining the last portions of ore from their Budlle holes, Buddling ought to no longer to be suffered. There were periods when the Limestone District of Derbyshire was a vast Mining Waste.

The great draught of air which the chimneys of the cupolas occasioned seemed to render the operation inoffensive to the smelters employed in the cupola buildings as their appearance and length of time at which they continue to work at them sufficiently prove, where they live at a distance from their works as is usually the case; but the noxious fumes of the Cupola and Slag Mill Chimnies, descending by their weight on the ground, for a quarter mile or more around them, poison the herbage, so that cattle are affected and if continued there soon die of a disorder called the belland which will be noticed as affecting the health of the Inhabitants in some cases. As the Cupola Owners are obliged to pay rent to the adjoining farmers for the damage the smoke does to the Lands the most barren and rugged spots are chosen for the erection of Smelting Works, and they ought also to be in a more sequestered and unfrequented place than many of them are found in. After a lead work has existed for a long time it so affects certain spots where the fumes alight, that neither wood nor any other vegetable produce can exist in such spots.

APPENDIX B Copy of a letter sent to all veterinary surgeons in practice in the EMR :-

Veterinary Investigation Centre

Sutton Bonington

2 February 1979

Dear Colleague

SWAYBACK FORECASTS FOR THE SPRING OF 1979

There is a low risk of swayback this spring. Already this winter has produced more snow than any since 1963 so that 1979 is expected to be the most disease-free year since then. If there is further snow in February the risk of swayback will be very low. In areas - or on farms with a history of swayback as a regular occurrence, farmers are recommended to consult their veterinary surgeons about prevention. Although the incidence varies from year to year, certain areas are more prone to the condition than others. Past records suggest that following mild and open winters such as 1971 and 1975 the disease level is high; conversely severe winters such as 1955, 1958and 1963 are followed by a low incidence.

The presence of snow on the ground has two effects, which are both beneficial. It encourages the supplementary feeding in-lamb ewes, which will provide more copper than from winter grass alone. At the same time, it reduces the intake of soil-contaminated herbage, which is known to contain factors which reduce the availability of copper to the ewe. Observations indicate that up to the end of February, the number of days with snow on the ground provide a useful estimate of the occurrence of swayback. In most years, only a general comment is possible at the end of January since snowfall in February may prove to be the deciding factor.

This year however snowfall in January has been sufficient to conclude that the risk is low - and absence of snow in February will not change the

I shall be pleased to carry out blood copper estimations on a representative number of ewes from flocks where the copper status is uncertain or unknown. Housed ewe flocks would be expected to have a higher status but this may depend on the length of time the ewes have been fed and on the type of fodder. Ewes fed silage may be worth sampling.

Veterinary Investigation Officer

They die in agony, victims of a silent killer that has the scientists baffled

MYSTERY DEATH OF THE BIRDS

By TONY ROBINSON

A HITCHCOCK-STYLE horror story is unfolding on a quiet council estate where 98 birds have mysteriously dropped dead.

Their bodies showed no signs of injuries, but post-mortem examinations revealed that their lungs were horribly congested with blood.

Now a full doomwatch alert has been mounted because of fears that the mystery killer could strike down humans too.

All the dead birds were found within 50 yards of a factory whose products include non-stick coatings for pots and pans.

No evidence has so far been found to link the factory with the birds' deaths.

Talks called

Council officials are anxious not to cause panic among the 600 people who live on the council estate beside the factory at Earl Shilton, Leicestershire.

But tomorrow they will have discussions at the Environment Department's headquarters in London to decide what should be done.

Scientists from the department have already begun investigating the bizarre phenomenon, but so far they are baffled.

The local council have also set aside £1,000 for research into the mystery deaths.

Among the dead birds are six pheasants and four bantams belonging to Mr. Frank White of High Street, Earl Shilton.

He said: "I don't really know what happened

"In the morning they were all fit and healthy and at lunchtime dead and dying. They seemed to be gasping.

"I got on to the environmental health people. Everything has been checked. There are no organic poisons, herbicides, pesticides or anything of that nature."

Mr White added: "The ground near the factory was absolutely littered with dead and dying birds—sparrows and a robin."

A spokesman for the Imperial Group, parent company of the Plastic Coatings factory at Earl Shilton, said: "We are as concerned as anyone about this.

Best advice

"Whether it's us or not is impossible to say. We're getting the best advice we can.

"There are twelve factories in this country using the same process and there has been nothing like this at any of them."

The Earl Shilton factory employed about fifty to sixty people, he said, and there had been no union concern about health risks.

He added: "There is no problem at all with human health so far as we know."

Mr. Dinis Bown, socialist mayor of the Hinckley-Bosworth Council, who represents the area of the factory, said there was an infants' school and some old people's flats near the factory.

"I asked the council to take some urgent action," he said, "and we put £1,000 aside to do some tests.

"We'll be testing the atmosphere around the factory."

He went on: "We shall be making sure that the health of the people is not impaired, if there is something. We don't know at this stage that there is something.

"It might be a freak of nature for all I know. I don't want to scare people."

Mr. Maurice Jones, principal environmental health officer with the local council, said yesterday: "This could well be a situation similar to the canary in the coal mine—where although the canary dies, there is no harm to the pit men."

He added: "Certainly we have no indication of any unusual problems in the human population.

"Obviously since the birds are affected by their lungs it might be expected to affect human beings in the same way.

"Doctors in the area do not report any increase in chest ailments."

Mr. Jones said that the mysterious ailment had been taking its toll of birdlife for about nine months.

Was there any common factor to link the occasions when birds had dropped dead?

Cold weather

He said: "We noticed that on each occasion the weather was rather cold. We had almost frosty and snowy-type conditions when the deaths occurred.

"Whether the cold contributed to the incidents, we don't know."

APPENDIX C Extract from the *Sunday Mirror* of February 27, 1976

Tests on children for lead in blood

THREE children whose fathers work at a Darley Dale lead refinery have been sent to live with relatives while tests are made on the lead count in their blood.

The blood tests were ordered by Dr David P. Adams, Medical Officer to Matlock Urban Council following the receipt of a circular from the Department of the Environment urging that blood tests be carried out on pre-school children of workers in the lead industry.

The children, Stephen Firth (5), Deborah Marshall (5) and her sister Julie, aged 18 months, all spent two days at Derbyshire Children's Hospital last week having blood tests, and were reporting for further laboratory tests at the Hospital today.

LONDON ALERT

All the children live at Hurst Rise, Hurst Farm Estate, Matlock.

Their fathers work at the lead refinery of H. J. Enthoven and Sons Ltd.

Dr Adams told the Telegraph that in the built-up area of London it had been found that some children of lead workers had rather higher than normal levels of lead in their blood.

"To estimate the blood lead levels in children is not easy because it is not easy to get blood samples from a child other than from a finger prick, and blood lead estimates are done only in a few places and are subject to quite a degree of experimental error.

"Purely by chance a research team from St Mary's Hospital Medical School, London, happened to be visiting Derbyshire to do some rearch on children from the Matlock and Buxton areas to compare the two groups and we thought they could help us with this problem.

"We asked the team to look at children under five of workers at Enthoven's and from that it transpired that four children had rather high blood lead levels.

Children to have lead tests

By our Correspondent

Fourteen children living near a Derbyshire lead smelting plant are to enter hospital at Derby today for special tests to discover the levels of lead in their blood.

The tests have been ordered by Matlock urban council after renewed concern about the possible dangers of lead pollution facing people living near the Enthoven lead works at South Darley. Hundreds of other local children might have to undergo similar tests if today's checks reveal abnormally high lead counts.

Tests were carried out earlier this year after the children of some workers at the plant were found to have abnormally high lead levels. The tests today involve other children living near the factory.

Councillor David Savidge, the chairman of Matlock public health committee, said: "Sensitive equipment is also being used in all parts of the area to measure the lead content of the atmosphere." He said that the latest tests were prompted by London Weekend Television, which conducted private checks showing that some local children were suffering from abnormally high lead counts.

APPENDIX D Left. Taken from the *Derby Evening Telegraph* of 12 June 1972.

Right. Taken from the *Guardian* June 1972.

Towns for lead poison checks named

By CLARE DOVER

A HUNT for possible victims of poisoning among people living near lead factories will cover areas of Manchester, Newcastle-upon-Tyne, Bristol, Liverpool, Birmingham, Chester, Matlock, Market Harborough and Welwyn Garden City.

Medical officers of health are being asked to investigate by starting blood sampling programmes.

It was disclosed on Tuesday that children near a smelting works on the Isle of Dogs had abnormally high levels of lead in their blood. A spokesman for Tower Hamlets council said yesterday there was no danger to them although three might be sent to hospital for a check.

The contamination was believed to have arisen from particles of lead dust from the works. The lead may have settled on food and generally contaminated the surrounding environment.

20 miles range

There is evidence from an investigation carried out by a research team at University College, Swansea, that lead from a smelting works can settle as far as 20 miles away.

Grass 20 miles from the works, now closed, had a lead level dangerously high to cattle. The investigation took place following the death of a horse, and serious sickness among cattle.

Lead poisoning can cause brain damage, mental retardation, and in larger doses, can kill. Contamination is particularly dangerous as the metal tends to accumulate in the body.

APPENDIX E Extract from the *Daily Telegraph* of 23 February 1971

THE GUARDIAN

London — Wednesday April 5 1972 — 5p

Danger lead level near plant

By ANTHONY TUCKER, Science Correspondent

Lead contamination of pasture land likely to be hazardous to grazing animals has been found in an area surrounding an anti-knock lead compound factory near Northwich, Cheshire.

Field research carried out by the botany department at Manchester University has shown that lead levels in mosses and grass close to the factory—almost 2,000 parts per million—are among the highest ever recorded in grass.

Although there is a rapid fall-off away from the factory, levels in grass half a mile away are still two or three times those normal for rural areas. The Alkali Inspectorate has been told, but no comment was available yesterday from Associated Octel at Ellesmere Port, the parent company.

Recent controversies over lead contamination have tended to centre on smelting works and on lead in paint, but little attention has been paid to pollution from factories manufacturing or handling the highly-poisonous lead alkyl compounds—tetraethyl and tetramethyl lead—used as anti-knock agents in petrol. Britain, a major exporter of these compounds, houses several potentially important centres of contamination.

The Manchester University work, now awaiting publication in scientific journals, is concerned primarily with the effects of heavy metals on field ecology. But it has revealed that pastures 400 yards from the factory contained grasses whose lead content at the time of sampling—the early winter of 1971—ranged up to 286 parts per million, three times the level normal in city roadside samples, and well above the level regarded as dangerous to grass-eating animals.

The scientific report points out that lead levels in grasses and mosses (mosses are rare in this area because of the high sulphur dioxide burden of the atmosphere) are likely to be highest at times of slow growth, and that the measurements are of total lead from unwashed samples.

There is no indication of the nature of the lead compounds escaping from the factory, although these could well be organic and therefore particularly dangerous.

While the area of contamination is not large, and does not involve a human population, it is still significant for it reveals once again the inadequacy of present control procedures for highly dangerous materials.

Describing the present programme of investigation into lead contamination, Mr Eldon Griffiths, Under-Secretary, Department of the Environment, said in a written reply yesterday that 20 lead works were being monitored. The activities were being coordinated by the Central Environmental Pollution Unit. Measures of lead levels in the blood of chidlren under school age living near the Stanton Lees lead works in Derbyshire would begin shorlly. Should these reveal any hazard to health, the necessary action would be taken immediately.

Politics of environment, page 12

APPENDIX F Extract from the *Guardian* 5 April 1972.

DERBYSHIRE

A.D.A.S.

FARMING NOTES

March, 1972. No. 109 The Racecourse, Nottingham Road, Derby

IN THIS ISSUE

VETERINARY STUDY GROUP ARTICLE

LEAD POISONING OF LAMBS ('RICKETTY' LAMBS)

Lead mining has been carried out in North Derbyshire for over 1500 years and evidence of this ancient industry can be seen in many areas in the limestone uplands and valleys. There are also old industrial sites in the surrounding gritstone areas where lead was prepared and sorted, ground in mills and then finally smelted. It is known that poisoning of cattle may occur near all these sites but it is not usually known that young suckling lambs may be also affected with lead poisoning. Such affected lambs are frequently badly lame and crippled. Fractures of the bones occur very easily and the animals are unable to follow the ewes to suckle. There are also changes in the kidneys and the animal weakens and dies.

It appears that the suckling lamb is considerably more at risk than the older animal whose rumen has started to function. Indeed, some old farmers have known that parts of their land were only suitable for grazing older lambs. Recently there has been more interest and recognition of this problem because of the disturbance of the old rakes or spoil heaps and further mineral extraction and road building. Any disturbances of the soil for the laying of pipes or altering gateways may unearth soil heavily contaminated with lead. Other cases of poisoning occur when buildings which have not previously been used for stock, are adapted for this purpose.

Treatment of affected lambs by your veterinary surgeon may be successful but it is most important to recognise if there is any danger on your farm and be prepared to fence off land, or exclude animals from certain buildings. It is suggested that advice should be sought whenever old spoil heaps are moved and there should be as little contamination as possible of surrounding grazing.

If you suspect that your lambs have been affected in this way, it is suggested that you approach your veterinary surgeon who will be pleased to arrange for samples of your soil and pasture to be examined for their lead content.

F. G. CLEGG,
DVO (VI)
Veterinary Investigation Centre,
Sutton Bonington.

APPENDIX G The issue of Derbyshire farming Times March 1972 published by the Agricultural Development and Advisory Service.

APPENDIX H

Page 88 Reclamation and Management of Metalliferous Mining Sites. (HMSO 1994)

7.8 Site : TIDESLOW/HIGH RAKE

7.8.1 Profile

County: Derbyshire

District: Derbyshire Dales

Geology: Carboniferous limestone with igneous intrusion.

Metals mined: Lead

Date last mined: c.1800

Status (1991); Naturally vegetated spoil heaps and shafts. Tideslow Rake is both an SSSI for both botanical reasons and a scheduled ancient monument.

7.8.2 Site History. Tideslow Rake was worked in medieval times and is recorded as being very productive by the 12th Century. By the 17th Century the workings were 300 ft deep and underneath an igneous horizon. This is the earliest recorded example in Derbyshire of this being achieved. Extraction at Tideslow Rake had ceased by about 1800 and the site has been subject to the formalising of a footpath and tree planting in recent times.

Site characteristics. Tideslow Rake is of both botanical and archaeological interest. The spoil heaps have been apparently little disturbed since mining ceased in 1800. From a botanical point of view the site is diverse and supports a large range of upper and lower metallophytic and limestone loving plants many of which were much more widespread only a few years ago. The site is of educational importance because of longstanding ecological and biogeochemical research which has been carried on there. Part of the site is sheep grazed and looks as though it has been fertilised.

This stretch of rake is much less divers in species than the rest. High Rake is managed by the Peak Park Planning Board following a tree planting scheme in the 1960's. This scheme also involved removal of fly tipped waste and formalisation of a footpath. In other areas the ground cover is lush and has been affected by soil imports or other ameliorants. Nevertheless even this area though different in character retains some interest and has good specimens of the Fragrant Orchid as well as many other limestone plants.

7.8.3 Assessment. This site should be managed for its botanical archaeological interest and some areas may benefit from occasional disturbance to maintain a colonising metalliferous flora. If possible the grazed area would benefit from restrictions on fertilizer use and even removal of grazing animals to allow it to return to a more natural sward.

VIII. APPENDICES

IX. REFERENCES

A

A Commercial Research Group (Aflatoxicosis) (1964)

Veterinary Record **76**, 498.

Allcroft, R (1950) Lead as a nutritional hazard to livestock.
Distribution of lead after ingestion of various lead compounds.
Journal of Comparative Pathology **60**, 190-208

Allcroft, R (1951) Lead poisoning in cattle and sheep.
Veterinary Record **63**, 583-590

Allcroft, R (1952) Conditioned copper deficiency in sheep and cattle in Britain.
Veterinary Record **64**, 17-24

Allcroft, R (1954) Fluorosis.
State Veterinary Journal **9**, 1-9

Allcroft, R and Blaxter, K L (1950) Lead as a nutritional hazard to livestock V. The toxicity of lead to cattle and sheep and the evaluation of the lead hazard under farm conditions.
Journal of Comparative Pathology **60**, 209-218

Allcroft, R and Carnaghan, R B A (1963) Groundnut toxicity: an examination for toxins in human food products and from animals fed toxic groundnut meal.
Veterinary Record **75**, 259-263

Allcroft, R, Clegg, F G and Uvarov, O (1959) Prevention of swayback in lambs.
Veterinary Record **71**, 824-827

Allcroft, R and Lewis, G (1956) The copper/molybdenum ratio of diets and the occurrence of copper deficiency in cattle.
Overdruck uit het Landbouwkundig Tijdschrift, **68**, Jaargang No 8.

Allen, W M and Sanson, B F (1989) Accidental contamination of the public water supply at Lowermoor, Camelford: an assessment of the possible veterinary consequences. Veterinary Record **124**, 479-482

Alloway, B J (1973) Copper and molybdenum in swayback pastures. Journal of Agricultural Science (Cambridge) **80**, 521-524

Alloway, B J and Davies, B E (1971) Heavy metal content of plants growing on soils contaminated by lead mining. Journal of Agricultural Science, (Cambridge) **76**, 321-332

Andrews, R T and Longcore, J R (1969) Transactions of the 34th North American Wildlife and Natural Resources Conference, Washington

Appleyard, W T (1986) Outbreak of bovine abortion attributed to ergot poisoning. Veterinary Record **118**, 48

Appleyard, W T and Mollison, A (1985) Suspected bovine botulism associated with broiler litter waste. Veterinary Record **116**, 522

Archer, R K and Jeffcott, L B (1975) Comparative Clinical Haematology. Blackwell Scientific Publications, Oxford

Aronson, A L (1972) Lead poisoning in cattle and horses following long-term exposure to lead. American Journal of Veterinary Research **33**, 627-629

Ashley, L M, Halver, J E , Gardner, W K and Wogan, G N (1964) Hepatoma and aflatoxicosis in trout. Federation Proceedings **23**, 105

Ashton, N, Barnett, K C, Clay, C E and Clegg, F G (1977) Congenital nuclear cataract in cattle. Veterinary Record **100**, 505-508

Asplin, F D and Carnaghan, R B A (1961) The toxicity of certain groundnut meals for poultry with special reference to their effects on ducklings and chickens. Veterinary Record **37**, 1215-1219

B

Bagley, G E, Locke, N L and Nightingale, G T (1967) Lead poisoning in Canada Geese in Delaware. Avian Diseases **11**, 601-608

Bailey J, Wrathall, A E and Mantle, P G (1973) The effect of feeding ergot to gilts during early pregnancy. British veterinary Journal **129**, 127-130

Ballad, R V, Holman, D W, Henecke, E W, Johnson, J E, Manual, O K and Nicholson, L M (1976) The monitoring of I-129 and I-131 in the environment. Health Physics **30**, 345-346

Barltrop, D (1975) Archives for Industrial Hygiene and Toxicology **26** (Supplement), 81

Barnes, J M and Butler, W H (1964) Carcinogenic activity of aflatoxin to rats. Nature **202**, 1016

Baxter, P J (1991) Major chemical disasters. British Medical Journal **302**, 61-62

Bayliss, M, Ineson, P R and Rorrison, I H (1979) The extent of belland ground adjacent to Tideslow and Maiden Rakes. Bulletin of the Peak District Mines Historical Society **7**, 153.

Bazell, J (1971) Lead poisoning: zoo animals may be the first victims. Science **173**, 130-131

Bennetts, H W (1933) Botulism of sheep in Western Australia and its association with Sarcophagia. Journal for the Council of Scientific and Industrial Research **6**, 137-144

Bennetts, H W (1932) Enzootic ataxia of lambs in Western Australia. Australian Veterinary Journal **8**, 137-142

Bennetts, H W and Chapman, F E (1937) Copper deficiency in Western Australia; a preliminary account of the aetiology of enzootic ataxia of lambs and anaemia of ewes. Australian Veterinary Journal **13**, 138-139

Berg, C R, Saxegaard, F and Tiefge, J (1975) Another outbreak of botulism in cattle. Norsk Veterinaertidsskkrift **87**, 238-241

Birkhead, M (1982) Causes of mortality in the Mute swans *Cygnus olor* in the River Thames. Journal of Zoology **198**, 15-25

Birkhead, M, Luke,B and Mann,S (1982) Intracellular localisation of lead in the tissues of the mute swan. Tissue and Cell **14**, 691

Birkhead, M (1983) Lead levels in the blood of Mute Swans on the River Thames. Journal of Zoology **199**, 59-73

Blakemore, F, Bosworth, T J and Green, H H (1948) Industrial fluorosis of farm animals in England attributable to the manufacture of bricks,the calcining of ironstone and to enamelling processes. Journal of Comparative Pathology **58**, 267-301

Blandford, T B, Roberts, T A and Aston, W L G (1969) Losses from botulism in mallard duck and other water fowl. Veterinary Record **85**, 541-543

Blandford, T B and Roberts, T A (1970) An outbreak of botulism in broiler chicks. Veterinary Record **87**, 258-261.

Blandford, T B, Seamon, P J, Hughes, R J, Pattison M and Wilderspin, M P (1975) A case of polytetrafluorethylene poisoning in cockatiels accompanied by polymer fume fever in the owner. Veterinary Record **92**, 175-176

Blaschko, H (1947) Inhibition of catechol bacteriostasis by molybdates. Nature, London **159**, 373

Blaxter, K L (1950) Lead poisoning of cattle. II The absorption and excretion of lead by sheep and rabbits. Journal of Comparative Pathology **60**, 140-159

Blaxter, K L and Allcroft R (1950) Lead as a nutritional hazard to farm animals. I The determination of lead in biological materials. Journal of Comparative Pathology **60**, 133-139

Bolter, E, Hemphill, B, Wixson, B, Butherus, D and Chen, R (1973) Trace Elements in Environmental Health **6**, 79-86

Blount, W P (1961) Turkey "X" disease. Journal of the British Turkey Federation **9**, 52, 55-58, 61, 77

Boonchuvit, B and Hamilton, P B (1975) Interaction of aflatoxin and paratyphoid infections in broiler chickens. Poultry Science **54**, 567

Boughton, I B and Hardy, W T (1934) Copper poisoning of sheep. Texas Agricultural Experimental Station Bulletin, No. 499.

Bourke, C A, Carrigan, M J and Love, S C J (1992) Flood plain staggers, a tunicaminuracil toxicosis. Australian Veterinary Association **69**, 228-229

Borland, E, Moryson, C J and Smith, G R (1977) Avian botulism and the high prevalence of Clostridium botulinum in the Norfolk Broads. Veterinary Record **100**, 106-109

Boyd, H and Reed, H C B (1961) Investigations into the incidence and causes of infertility in dairy cattle - influence of kale feeding, milk production and management factors associated with farming intensity."
British Veterinary Journal **117**, 192-200

Bradley-Jones, J (1965) Ergot and ergotism.
National Agricultural Advisory Service Quarterly Review **68**, 157-164

Bradley, R, Terlecki, S and Clegg, F G (1982) The pathology of a retinal degeneration of Friesian cows.
Journal of Comparative Pathology **92**, 69-83

Bramley, J V (1990) Fluospar mining in Derbyshire.
Mining Magazine **163(5**), 328-333

British Medical Journal (1975) More on the aflatoxin-hepatoma story.
Leading article 21 June 1975 No, **5972**, 647-648

Buck, W B (1970) Lead and organic pesticide poisonings in cattle.
Journal of the American Veterinary Medical Association **156**, 1468-1472

Burgess, J (1981) How careless anglers kill our swans.
Nottinghamshire Countryside 1981 pp 123-124

Burns, K N and Allcroft, R (1964) MAFF Animal Disease Survey No.2
London, HMSO

Burrows, G E (1981) Lead toxicosis in domestic animals: a review of the role of lead mining and primary lead smelters in the United States.
Veterinary and Human Toxicology **23**, 337-343

Burrows, G E, Sharp, J W and Root, R G (1981) A survey of blood lead concentrations in horses in the North Idaho lead/silver belt.
Veterinary and Human Toxicology **23**, 328-330

Butler, W H (1966) Acute toxicity of aflatoxin B1 in guinea pigs.
Journal of Pathology and Microbiology **91**, 277-280

Butler, E J, Nisbet, D I and Robertson, J M (1957) Osteoporosis in lambs in a mining area. Journal of Comparative Pathology **67**, 378-396

Buxton, J C and Allcroft, R (1955) Industrial molybdenosis of grazing cattle. Veterinary Record **67**, 273-276

C

Campbell, A and Hodgson, L (1994) The Veterinary Poisons Information Service - an outline of the service and review of enquiries in 1993. Proceedings of the 6th International Congress of the European Association for Veterinary Pharmacology and Toxicology, Edinburgh 7-11 August 1944

Carnaghan, R B A (1965) Hepatic tumours in ducks fed a low level of toxic groundnut meal.
Nature **208**, 308

Carnaghan, R B A and Allcroft, R (1962) Groundnut toxicity.
Veterinary Record **74**, 925-926

Carnaghan, R B A and Allcroft, R (1963) Groundnut toxicity: an examination for toxin in human food products from animals fed toxic groundnut meal.
Veterinary Record **75**, 259-263

Carson, T L, van Gelder, G A , Karas, C G and Buck, W B (1974) Slow learning in lambs pre-natally exposed to lead.
Archives of Environmental Health **29**, 154-156

Cawley, G D, Collings, D F and Dyson, D A (1977) Nitrate poisoning.
Veterinary Record **101**, 304-305

Chang, C F and Hamilton, P B (1979) Impaired phagocytosis by heterophils from chickens during aflatoxicosis.
Toxicology and Applied Pharmacology **48**, 459

Chesney, A M, Clawson T A and Webster, B (1928) Endemic goitre in rabbits I. Incidence and characteristics.
Bulletin of John Hopkins Hospital **43**, 261-267

Chesney, R W L (1953) "Migram": a disease of sheep on the Romney marshes.
British veterinary Journal **109**, 257-268

Chiejina, S N and Clegg, F G (1960) Some observations on the epidemiology of ostertagiasis in calves in Britain: an analysis of laboratory diagnosis and field data for 1974 to 1976. British Veterinary Journal **72**, 541-55

Christian, R G and Tryphonas, L (1971) Lead poisoning in cattle: brain lesions and haematological changes. American Journal of Veterinary Research **32**, 203-211

Clegg, F G (1956) An outbreak of copper poisoning in sheep. Veterinary Record **68**, 332-333

Clegg, F G (1959) A convulsive syndrome in sheep. Veterinary Record **71**,824-827

Clegg, F G (1963) Caution with kale and rape. Agriculture **10**, 471-473

Clegg, F G (1965) Swayback can be prevented. Agriculture **112**, 6-9

Clegg, F G (1966) Haemoglobinaemia of cattle associated with the feeding of kale and other *Brassicae* species. IV International Tagung der Weltgesellschaft für Buiatrik. August 1966, Zurich

Clegg, F G (1978) Lead pollution in Derbyshire due to mining and industry. State Veterinary Journal **33**, 41-4

Clegg, F G, Blandford, T B and Bayliss, J (1965) Possible relation of silage feeding to listeriosis in sheep. Veterinary Record **77**, 909-910

Clegg, F G and Bryson, H (1962) An outbreak of groundnut poisoning in store cattle attributed to Brazilian groundnut meal. Veterinary Record **74**, 992-994

Clegg, F G and Evans, R K (1962) Haemoglobinaemia of cattle associated with the feeding of *Brassicae* sp. Veterinary Record **74**, 1169-1176.

Clegg, F G and Evans, R K (1974) Suspected botulism in cattle.
Veterinary Record **95,** 540

Clegg, F G, Hebert, C N and Hunt, A (1983)
Incidence of hypocupraemia in cattle herds in the East Midlands.
Veterinary Record **112,** 34-35

Clegg, F G , Terlecki, S and Bradley, R (1981) Blindness in dairy cows.
Veterinary Record **109,** 101-103

Clegg, F G and Hunt, A E (1975) Salmonella infection in mute swans (*Cygnus olor*).
Veterinary Record **97,** 373

Clegg, F G, Jones, T O, Smart, J C and McMurtry, M J (1985) Bovine botulism associated with broiler waste.
Veterinary Record **117,** 22

Clegg, F G and Rylands, J M (1966) Osteoporosis and hydronephrosis of young lambs following the ingestion of lead.
Journal of Comparative Pathology **76,** 15-22

Clegg, F G and Watson, W A (1960) Ryegrass staggers in sheep.
Veterinary Record **72,** 731-733

Clements, F W and Wishart, J W (1956) A thyroid-blocking agent in the etiology of endemic goiter.
Metabolism Clinical and Experimental **5,** 623-629

Cockburn, R S, Eaton, G, Hudson, J R, Morgan, K G Wood, K and Worden, A (1955)
Acute poisoning of cattle by common ragwort *(Senecio jacobaea* L)
Veterinary Record **67,** 640

Coggon, D (1991) Camelford revisited.
British Medical Journal **303,** 1280-128

Coggon, D (1995) Assessments of exposure to environmental pollutants.
Occupational and Environmental Medicine **52**, 562-564

Colbourn, P (1976) The application of geochemical reconnaissance data to trace element pollution in agriculture.
Ph D Thesis, University of London

Colbourn, P and Thornton, I (1978) Lead pollution in agricultural soils.
Journal of Soil Science **29**, 513-526

Coté, F T (1944) Rape poisoning in cattle.
Canadian Journal of comparative Medicine **8**, 38-41

Coulombe, R A (1993) Biological action of mycotoxins.
Journal of Dairy Science **76**, 88O-891

Craste, L and Burgatsacaze, V (1995) Wild cervidae as bioindicators of cadmium pollution.
Revue de Medecine Vétérinaire **146**, 583-592

Cunningham, I J, Swan, J B and Hopkirk, C S M (1944) The symptoms of ergot poisoning.
New Zealand Journal of Science and Technology **A 26**, 121-124

Cunningham. I J (1959) Parenteral administration of copper to sheep.
New Zealand Veterinary Journal **7**, 15-17

D

Davies, B E (1983) A graphical estimation of the normal lead content of some British soils.
Geoderma **29**, 67-75

Department of the Environment (1974) Lead in the environment and it significance to man.
Central Unit on Environmental Pollution. HMSO, London

Department of the Environment (1983) Guidance on the Assessment and Redevelopment of Contaminated Land. ICRCL 59/83 HMSO, London

Dick, A T (1953) Experimental production of a staggers syndrome in ruminants by a tremorgenic *Penicillium* from soil. Australian Veterinary Journal **29,** 18-26

Dick, A T, Dewey, P W and Garthorne, J M (1975) Thiomolybdates and copper - and molybdenum - sulphur interaction in ruminant nutrition. Journal of Agricultural Science (Cambridge) **85,** 567-568

Djuric D, Kerin, Z, Graovac-Leposavis, L, Novak, L and Kop, L (1971) Environmental contamination by lead from a mine and smelter. Archives of Environmental Health **23,** 275-292

Dodd, D C and Coup, M R (1957) Poisoning of cattle by certain nitrate-containing plants. New Zealand Veterinary Journal **5,** 51-54

Dodds, D C and Staples, E L J (1956) Lead poisoning of dogs. New Zealand Veterinary Journal **4,** 1

Dollahite, J W, Rowe, L D and Reagor, J C (1975) Experimental lead poisoning in horses and Spanish goats. Southwest Veterinarian **28,** 40-45

Dollahite, J W, Younger, R L Crookshank, H R (1978) Chronic lead poisoning in horses. American Journal of Veterinary Research **39,** 961-964

Donovan, P P, Feeley, D T and Canavan, P P (1969) Lead contamination in mining areas in Western Ireland. Journal of Science, Food and Agriculture **20,** 43-45

Doutre, M P (1967) Le botulisme animal au Sénégal. Bulletin de l'Office International des Epizooties **67,** 1497-1515

Dunlop, G and Wells, H E (1938) "Warfa" ('swayback') in lambs in north Derbyshire and its prevention by adding copper supplements to the diet of the ewes during pregnancy.
Veterinary Record **50,** 1175-1182

Dunlop, G, Innes, J R M and Shearer, G D (1939) "Swayback" studies in north Derbyshire. I. The feeding of copper to pregnant ewes in the control of "swayback".
Journal of Comparative Pathology **52,** 259-265

E

Eden, A (1939) The influence of varying copper intake on normal blood copper Northumbrian sheep.
Journal of Comparative Pathology **52,** 249-259

Eden, A and Green, H H (1939) The fate of copper in the bloodstream.
Journal of Comparative Pathology **52,** 301-305

Eden, A and Green, H H (1940) 143. Micro-determination of copper in the blood stream.
Biochemical Journal **34,** 1202

Edwards, B (1979) Historic Totley.
Shape Design, Sheffield

Edwards, C M (1953) Ergot poisoning in young cattle.
Veterinary Record **65,** 158-159

Edwards, E P (1924) Notes re lead poisoning.
Veterinary Journal **80,** 81-86

Edwards, W C, Clay, B R and Buck, W B (1976) Determination of lead levels in beef randomly selected from supermarkets.
Veterinary Toxicology **18,** 70-72

Egan, D A and O'Cuill, T O (1969) Open cast lead mining areas; a toxic hazard grazing stock.
Veterinary Record **84,** 230

Egan, D A and O'Cuill, T O (1970) Cumulative lead poisoning in horses in a mining area contaminated with galena. Veterinary Record **86**, 736-738

Elinder, G C, Stenstrom T, Piscator, M (1980) Water hardness in relation to cadmium accumulation and microscopic signs of cardiovascular disease in horse. Archives of Environmental Health **35**, 81-84

Ellenberger and von Hofmeister (1883) Die physiologischen Wirkungen des Kupfers auf den Organismus der wiederkunden Haussaugetiere. Archive für Wissenschaftliche und praktischer Tierarzt **9**, 325-355

Evans, E T R (1951) Kale and rape poisoning in cattle. Veterinary Record **63**, 348-349

F

Farey, J (1811) A General View of the Agriculture and Minerals of Derbyshire. vol. 1. London: Macmillan

Farey, J (1817) A General View of the Agriculture and Minerals of Derbyshire. vol. 2. London : Macmillan.

Ferguson, W S, Lewis, A H and Watson, S J (1943) The teart pastures in Somerset. I. The cause of teartness. Journal of Applied Agricultural Science **33**, 44-51

Field, H I (1972) The Animal Health Division and ADAS. Veterinary Record **91**, 438

Fincham, I H (1954) "Chronic" copper poisoning of sheep. Veterinary Record **65**, 336

Fink-Gremmels, J (1994) Neurotoxic mycotoxins. Proceedings of the European Association for Veterinary Pharmacology and Toxicology 6th International Congress, Edinburgh 7-11 August 1994

Fink-Gremmels, J and Blom, M (1994) Rye-grass staggers linked to lolitrem B: a case report. Proceedings of the European Association for Veterinary Pharmacology and Toxicology 6th International Congress, Edinburgh 7-11 August 1994

Fischer, L R E (1954) Lead poisoning in a gorilla. Journal of the American Veterinary Medical Association **125**, 478-479

Fitzgerald, J N (1954) Molybdenum in oats. New Zealand Journal of Agriculture **89**, 619-620

Fjolstad, M and Klund, T (1969) An outbreak of botulism among ruminants in connection with ensilage feeding. Nordisk Veterinaermedicin **21**, 609-613

Flight, D M A, Lister, T R and Fordyce, C (1994) The identification of mining related contaminants in the UK using high resolution geochemical mapping : examples from North-east England and North Wales.
Environmental Geochemistry and Health **16 (2)**, 91-92

Food Standards Agency (1997) Report by Professor P James 30 April
HMSO, London

Forbes, N A and Jones, D E (1997) PTFE toxicity in birds.
Veterinary Record **140,** 512

Ford, C M F (1956) Nutritional factors and bovine infertility in the East Midlands.
British Veterinary Journal **112,** 177-188

Ford, C M F (1960) Iron content of drinking water.
Veterinary Record **72,** 785-786

Ford, C M F (1972) Fluorosis in a dairy herd.
Veterinary Record **90,** 611

Ford, C M F (1973) A cure for nutritional fertility.
Veterinary Record **91,** 130

Ford, T D and Rieuwerts, J H (1968) Lead mining in the Peak District.
Peak District Mines Historical Society, Geology Department, University of Sheffield

Frape, D L and Pringle, J D (1984) Toxic manifestations in a dairy herd consuming haylage contaminated by lead.
Veterinary Record **114,** 615-616

Fullerton, P M (1966) Chronic peripheral neuropathy produced by lead poisoning guinea pigs.
Journal of Experimental Neuropathology and Neurology **25,** 214-236

Furr, A K, Stoewsand, G S, Bache, C A, Gutenmann, W H and Lisk, D J (1975)
Multi-element residues in guinea pigs fed sweet clover grown on fly ash.
Archives of Environmental Health **30**, 244-248

Furr, A K, Bache, C A, Gutenmann, W H and Lisk, J D (1976) Multi-element uptake by vegetables and millet grown in pots on fly ash amended soil.
Journal of Agriculture, Food and Chemistry **24**, 885-888

Furr, A J, Parkinson, T F, Heffron, C L, Reid, J T, Haschek, W M, Gutenmann, W, Bache, C A, St John, L E, Pakkola, I S and Lisk, J D (1978)
Elemental content of tissues and excreta of lambs, goats and kids fed on white sweet clover growing on fly ash.
Journal of Agriculture, Food and Chemistry **24**, 847-851

G

Gabbai, Lisbonne and Pourquier (1951) Ergot poisoning at Pont St Esprit.
British Medical Journal Sept 15, 650-651

Gaiger, S H (1917) Renguera: a paralytic sheep disease in Peru.
Journal of Comparative Pathology and Therapeutics **30**, 185-209

Gallagher, R T, White, E P and Mortimer, P H (1981) Ryegrass staggers: isolation of potent neurotoxins lolitrem A and lolitrem B from staggers producing pastures.
New Zealand Veterinary Journal **29**, 189-190

Gardener, W A and Hall-Patch (1968) Molybdenosis in cattle grazing downwind from an oil refinery.
Veterinary Record **82**, 86-87

Gardner, J A (1924) The bellanding, or poisoning of land by mine refuse.
Veterinary Journal **80**, 13-19

Gerhardsson, L, Hagmar, L, Rylander, L and Skerfving, S (1995) Mortality and cancer incidence among secondary lead smelter workers.
Occupational and Environmental Medicine **52**, 667-672

Getz, L L, Haney, A W, Larimore, P E, McNurney, J W, Leland, H V, Price, P W, Rolfe, G L, Wartman, R L, Hudson, L J, Solomon, R L and Reinbold, P K (1977)
Lead in the Environment, U S National Science Foundation, Washington, D C

Gibson, L A S (1986) Botulism in dairy cows.
Veterinary Record **118**, 309

Gillham, E W F (1980) Trace elements in soils and ashes - a review.
Central Electricity Generating Board. MID / SSD /80 / 0002 / R

Gillham, E W F and Lewis, G (1971) Studies on animal health on land restored with pulverised fuel ash.
Central Electricity Generating Board. SSD / MID / 235 /71

Gillham, E W F and Lewis, G (1980) Further studies of health of animals on land restored with pulverised fuel ash.
Central Electricity Generating Board. MID / SSD / 80 / 0028 / R

Gireer, G S and Ratchman, A F (1966) Boron levels in lambs.
Dokl vses Akad sel 'Khoz Nauk **6**, 40

Goodman, G T and Roberts, T M (1971) Plants and soils as indicators of metals in air.
Nature, London **231**, 287-292

Gordon, C C (1968) East Helena Reports for Director of Air Pollution 16 December cited by Waldron and Stöfen (1974)

Green, H H (1946) An outbreak of industrial fluorosis in cattle. Proceedings of the Royal Society of Medicine **39**, 795

Green, H H (1947) Trace elements in relation to health of livestock. Annals of Applied Biology **43**, 159-165

Greenhalgh, J F D, Sharman, G A M and Aitken, J N (1969) Kale Anaemia I. The toxicity to various species of animal of three types of kale. Research in Veterinary Science **10**, 64-72

Greenhalgh, J F D (1971) Problems of Animal Disease, in 'The Future of *Brassicae* crops', Rowett Research Institute, Aberdeen

Greenhalgh, J F D, Aitken, J N and Gunn, J B (1971) Kale anaemia III. A survey of kale feeding practices and anaemia in cattle on dairy farms in England and Scotland. Research in Veterinary Science **13**, 15-22

Grieg-Smith, P W, Fletcher, M R, Hunter, K, Quick, M P, Ruthven, A D and Shaw, I C (1990) Investigations of suspected poisoning of animals by pesticides in Great Britain. MAFF Report of the Environmental Panel of the Advisory Committee on Pesticides, HMSO, London

H

Hall, S A, Dawson, P S and Davies, G (1980) VIDA II: a computerised recording system for veterinary investigation centres in Great Britain.
Veterinary Record **106**, 260-264

Hammond, P B and Aronson, A L (1964) Lead poisoning in cattle and horses in the vicinity of a smelter.
Annals of the New York Academy of Sciences **3**, 596-611

Hammond, P B, Wright, H N and Roepke, M H (1956)
University of Minnesota Agricultural Station Technical Bulletin No. 21

Harbourne, J F, Macrae, C T and Watkinson, J (1968) An unusual outbreak of lead poisoning in calves.
Veterinary Record **83**, 515-517

Hardisson, J R (1977) Chemical control of ergot in field plots of *Lolium perenne*.
Plant Disease Report **61**, 845

Hardy, A R, Fletcher M R and Stanley, P I (1986) Pesticides and wildlife incidents investigated by MAFF.
State Veterinary Journal **40**, 182-192

Hayes, J P (1978) Soil and dung contamination of silage by flail mowers and harvesters.
Advisory Leaflet A425, MAFF London

Hell, P, Stanovsky, M and Zilinec, M (1995) Dental fluorosis of deer in the vicinity of a Slovakian aluminium factory.
Zeitschrift fur Jagdwissenschaft **41**, 117-125

HMSO (1961) Select Committee on Estimates report on Agriculture.
London

HMSO (1979) Geology of the country north of Derby.
Memoirs for the 1 : 50,000 Geological sheet 125. London

HMSO (1987) ICRCL 59/83 Guidance on the assessment and redevelopment of contaminated land. London

HMSO (1990) ICRCL Guidance Note 70/90. Notes on the restoration and aftercare of metalliferous mining sites for pasture and grazing. London

HMSO (1994) The Reclamation and Management of Metalliferous Mining Sites.
Environmental Consultancy University of Sheffield and Richards Moorhead and Laing Ltd. HMSO, London

HMSO (1998) Food standards Agency. A Force for Change. (**Cm 3830**)

Hodgson, D R and Holliday, R (1966) The agronomic properties of pulverised fuel ash.
Chemistry and Industry May **14**, 1966, 784-790

Hopper, S A, Grieg, A and McMurray, C H (1986) Selenium poisoning in lambs.
Veterinary Record **116**, 569-570

Howe, J R and Hunt, A E (1984) Swan thyroid glands and river algae as indicators of Iodine-125 and Iodine-131 in the river Trent and its tributaries.
The Science of the Total Environment **35**, 387-401

Howe, J R, Lloyd, M K, Hunt, A E and Clegg, F G (1984) The origin of I-125 in animal thyroid glands.
Health Physics **46**, 244-245

Howe, J R and Bowlt, C (1992) Iodine-125 in Britain's drinking water supply.
Journal of Environmental Radioactivity **16**, 109-126

Humphries, W R, Mills, C F, Grieg, L, Roberts, D, Inglis, D and Halliday, G J (1986) Use of ammonium tetrathiomolybdate in treatment of copper poisoning in sheep. Veterinary Record **119**, 596-598

Hunt, A E (1975) Chronic lead poisoning in the Peak District of Derbyshire. M Phil Thesis, University of Nottingham

Hunter, A H, Eden, A and Green, H H (1945) Contributions to the study of swayback in lambs. I. Field experiments. Journal of Comparative Pathology **55**, 19-28

I

Ineson, P R (1983) Geological, geochemical, botanical and veterinary aspects of Pb, Zn, Cu, and Cd concentrations in the Pennines. Chronique de la recherche minière **47O**, 57-64

Innes, J R M and Shearer, G D (194O) "Swayback": a demyelinating disease of lambs with affinities to Schilder's encephalitis of man. Journal of Comparative Pathology **53**, 1-41

Ironside, W J (1943) Banham's Veterinary Posology and other Information for the use of Students and Practioners (7th edition). Baillière, Tindall and Cox, 7 & 8, Henrietta Street, Covent Garden, London

J

Jenkinson, J G (1958) Ergot infestation in the south-west of England. Plant Pathology **7**, 81-85

Johnston, T D and Jones, D I H (1966) Variations in the thiocyanate content of kale varieties. Journal of Science, Food and Agriculture **17**, 7071

Jones, T O and Jones, D R (1977) Nitrate/nitrite poisoning of cattle from forage crops.
Veterinary Record **101**, 266-267

Jones, T O (1982) Suspected ammonium nitrate fertiliser poisoning in cattle.
Veterinary Record **111**, 211-212

Jones, T O (1988) Nitrate/nitrite poisoning in cattle.
In Practice **10** (5), 199-203

K

Kellner, O (1915) The Scientific Feeding of Animals.
Duckworth and Co. London

Keppler, J G and de Jongh, H (1964) Aflatoxin - occurrence and composition.
Food and Cosmetic Toxicology **2**, 675

Kidd, A R M (1990) Adverse reactions to veterinary medicines.
State Veterinary Journal **44**, 170-181

Kiernan, D and Van der Noort, R (1992) Bole smelting in Derbyshire.
Boles and Smelting Seminar. Historical Metallurgy Society Ltd.
Peak District Mining Museum, Matlock Bath, Derbyshire.

Knight, H D and Burau, R G (1973) Chronic lead poisoning in horses.
Journal of the American Veterinary Association **162**, 781-786

Kowalczyk, D F (1976) Lead poisoning in dogs at the University of Pennsylvania Veterinary Hospital.
Journal of the American Veterinary Medical Association **168**,428-432

Kradel, D C, Adams, W M and Guss, S B (1965) Lead poisoning and eosinophilic meningo-encephalitis.
Veterinary Medicine **60**, 1045-1050

Krishnamachari, K, Bhat, R V, Nagarajan V and Tilak, T B G (1975)
Hepatitis due to aflatoxicosis-an outbreak in western India.
Lancet **1**:1061

L

Lagerwerff, J V, Brower D L, and Biersdorf, G T (1973) Accumulation of cadmium, copper, lead and zinc in the proximity of a smelter. Trace Elements in Environmental Health **6**, 71-78

Lancaster, M C, Jenkins, F P and Philips, J McL (1961) Toxicity associated with certain samples of groundnuts. Nature **192**, 1095

Landrigan, P J (1991) Current issues in the epidemiology and toxicology of occupational exposure to lead. Toxicology and Industrial Health **7**, 9-14

Langgemach, T, Deutrich,V and Metz, R (1995) Investigation of the heavy metal concentrations in game animals in areas treated with human sewage. Tierärztliche Umschau **50**, 480

Larsen, A A (1969) Report of the Inter Agency Committee on Environmental Study. Cited by Waldron and Stöfen (1974)

Latour, H (1955) Ergotism at Pont-Saint-Esprit. Revue Pathlogique générale et comparative **55**, 1444-1446

Lee, J A and Tallis, J H (1973) Regional and historical aspects of lead pollution in Britain. Nature **245**, 216-218

Leigh, C (1700) Natural history of Lancashire, Cheshire and the Peak District of Derbyshire. Vol.**1** Oxford

Linton, R G (1927) Animal Nutrition and Veterinary Dietetics. Green and Son Limited, Edinburgh

Little, P and Martin, M H (1972) A survey of zinc, lead and cadmium in soil and natural vegetation surrounding a smelting complex. Environmental Pollution **3**, 241-254

Little, T (1998) Changes to the Veterinary Laboratories Agency. Veterinary record **142**, 286

Logner, K R, Neathery, M M W, Miller, W J, Gentry, R P, Blachkburn, D M and White, F D (1984) Lead poisoning of cattle. Journal of Dairy Science **67**, 1007-1013

Loosmore, R M and Harding, J D J (1961) A toxic factor in groundnut causing liver damage in pigs. Veterinary Record **73**, 1362-1364

Loosmore, R M and Markson, L M (1961) Poisoning of cattle by Brazilian groundnut meal. Veterinary Record **73**, 813-814

Lowermoor incident Health Advisory Group (1989 and 1990). Water pollution at Lowermoor north Cornwall. Truro, Cornwall and Isles of Scilly Health Authority

Lloyd, M K (1983) Environmental Toxicity. Trace elements in animal production and veterinary practice. Occasional Publication No. 7, British Society of Animal Production

Luxton, D (1998) Changes to the Veterinary Laboratories Agency. Veterinary Record **142**, 286

Lyman, R (1986) Polytetrafluorethylene toxicity. Clinical Avian Medicine and Surgery. Ed. Harrison, G J and Harrison, L R. W B Saunders, Philadelphia

M

Macdonald, J W, Goater, R, Atkinson, N K and Small, J (1990) Further deaths in Scottish swans (*Cygnus olor*). State Veterinary Journal **44**, 81-93

McDonald, W A (1942) A "staggers" syndrome in sheep and cattle associated with grazing on *Phalaris tuberosa*. Australian Veterinary Journal **18**, 182-189

McGowan, J C and Brian, P W (1947) Inhibition of catechol bacteriostasis by molybdates.
Nature, London **159**, 373

McLeavey, B J (1977) Lead poisoning in dogs.
New Zealand Veterinary Journal **25**, 395-396

McLeavey, B J (1979) Lead poisoning: a veterinary responsibility?
New Zealand Veterinary Journal **27**, 199

McLoughlin, M F, McIlroy, S G and Neill, S D (1988) A major outbreaks of botulism of cattle being fed ensiled poultry litter.
Veterinary Record **122**, 579-581

MacPherson, A, Milne, E and MacPherson, A J (1997) Copper poisoning of ewes.
Veterinary Record **141**, 631

MAFF (1972) Working party on the monitoring of foodstuffs for heavy metals.
Second Report: Survey of lead in food. HMSO, London

MAFF (1975) Survey of lead in food: first supplementary report. Fifth Report of the working party on the monitoring of foodstuffs for heavy metals. HMSO, London

MAFF (1982) Survey of Lead in Food: Second Supplementary Report.
HMSO, London

MAFF (1991) Codes of recommendations for the welfare of livestock.
Cattle
HMSO, London

MAFF (1995a) Pesticide poisoning of animals 1994. Investigations of suspected incidents in the UK. A report of the Environment Panel of the Advisory Committee on Pesticides.
HMSO, London

MAFF (1995b) Veterinary Investigation Surveillance Report 1995 and 1988-95. HMSO, London

MAFF (1996) Pesticide poisoning of animals 1995: investigations of suspected incidents in the United Kingdom. A report of the Environmental Panel of the Advisory Committee on Pesticides. MAFF Publications, London

Mahajan, M R (1932) Annual Report, VIO, Hyderabad.(Andhra Pradesh) Cited by Brahm Dutt(1972) in Deficieny Diseases of Livestock, Indian Council of Agricultural Research, New Delhi.

Majumdar, B N and Ray, S N (1946) Fluorine intoxication of cattle in India. 2. Effect of fluorosis on mineral metabolism. Indian Journal of Veterinary Science **16,** 107

Mantle, P B, Mortimer, P H and White, E P (1978) Mycotoxic tremorgens of *C paspali* and *P cyclopium.* Research in Veterinary Science **24,** 49-55

Martin, W S, Meak, A H and Willweberg, P (1987) Veterinary Epidemiology: Principles and Methods. Iowa University Press, Ames

Mayon-White, E T (1993) How should another Camelford be avoided? British Medical Journal **307,** 398-399

Medvedev, (1995) Concentrations of cadmium, lead and sulphur in tissues of wild, forest reindeer from north west Russia. Environmental Pollution **90,** 1-5

Medical Research Council (1997) Report of a Working Group on the 'Collection of Environmental Exposure Data'. Working Group Chairman D Coggon under the MRC Committee on Toxic Hazards in the Environment and Workplace, London

Mellanby, E (1930) The relation of diet to health. British Medical Journal **1,** 67

Mellanby, K (1973) Evidence submitted to the Commission on Mining in the Environment.
Institute of Biology, London

Melrose, D R and Brown, B B (1962) Some observations on the possible effect of kale feeding on fertility of dairy cattle.
Journal of Reproduction and Fertility 4, 232

Menna, di M, Mantle, P G and Mortimer, P M (1976) Experimental production of staggers syndrome in ruminants by a tremorgenic *Penicllium* from soil.
New Zealand Veterinary Journal **29**, 18-26

Miller, D M, Stuart, B P, Cromwell, W A, Cole, R J, Goven, A and Brown, J (1978) Aflatoxicosis in swine: its effects on immunity and relationship to Salmonellosis.
American Association of Veterinary Laboratory Diagnosis **21**, 135

Mills, C F, Bremner, I, El-Galland, T T T, Dalgarno, A C and Young, B W (1978) Mechanisms of the molybdenum/sulphur antagonism of copper utilisation by ruminants.
Trace Elements in Metabolism in Man and Animals Vol **3**.
Freising University, Munich

Minervin, S (1967) On the parenteral-enteral method of administering serum in cases of botulism. Proceedings of the 5th International Symposium on Food Microbiology, Moscow.
Chapman and hall, London

Mitchell, C A (1940) Lead poisoning of a dog.
Canadian Journal of Comparative Medicine **4**, 170-173

Mitchell, R L and Reith, J W S (1966) Lead content of pasture herbage.
Journal of Science of Food and Agriculture **17**, 437-440

Miyake, I, Naito, I H, and Tsunoda, H (1940) Studies of toxin production of stored rice by parasitic fungi. Rice Utilisation Research Institute, Ministry of Agriculture and Forestry. Report No.1

Mueller, P K and Stanley, P (1970) Report No 87 State of California Department of Public Health, Air and Industrial Hygiene Laboratory report in Waldron and Stöfen (1974)

Mullins, J (1941) "Staggers" in animals. New Zealand Journal of Agriculture **62**, 169

Munro, D A and Solman, V E F (1967) Canadian Council of Resource Ministers background paper prepared for National Conference on pollution and our environment. October 1966 **1**, 1

N

Naerland, G (1948) Kobber forgitning hos sau (Copper poisoning in ewes). Norsk Veterinaertidsskrift **60**, 161-185

Nature Conservancy Council (1981) Report of the Working Group on Lead Poisoning of Swans. Nature Conservancy Council, London

Nichol, I, Thornton, I, Webb, J S, Fletcher, W K, Horsenail, R F, Khaleelee, J and Taylor, D (1970) Regional geochemical reconnaissance of the Derbyshire area. HMSO, London

O

Ogoma, J K, Yokota, K and Hayashi, S (1990) Infant botulism due to *Clostridium botulinum* type C toxin.
Lancet **336**, 1499-1450

Osweiler, G D, Buck, W B and Lloyd, W E (1973) Lead poisoning of cattle.
Clinical Toxicology **6**, 367-376

Ottoboni, F and Kahn, E (1970) Lead poisoning of animals.
Interim Report, California Department of Public Health

P

Paget, G E (1954) Exudative hepatitis of guinea pigs.
Journal of Comparative Pathology **67**, 393

Parker, W H and Rose, T H (1955) Molybdenum poisoning (teart) due to aerial contamination.
Veterinary Record **67**, 276-279

Paterson, J S, Crook, J C, Shand, A, Lewis, G and Allcroft, R (1962) Groundnut toxicity as the cause of exudative hepatitis (oedema disease) of guinea pigs.
Veterinary Record **22**, 639-640

Patterson, D S P and Roberts, B A (1979) Mycotoxins in animal feed stuffs.
Journal of the Ass of Official Analytical Chemists **63**, 1265-1267

Pearson, J K L (1956) Copper poisoning in sheep following the feeding of a copper supplemented diet.
Veterinary Record **68**, 766-768

Penny, R H C, David, J S E and Wright, A I (1961) Heinz-Ehrlich bodies associated with kale feeding.
Veterinary Record **73**, 747-748

Penny, R H C, David, J S E and Wright, A I (1964) Observations on the blood picture of cattle, sheep and rabbits fed on kale. Veterinary Record **76**, 1053-1059

Pettit, G D, Holm, L W and Rushworth, W E (1956) Lead poisoning in a dog. Journal of the American Veterinary Association **128**, 295

Pier, A C, Richard J L and Thurston, R J (1979) The influence of mycotoxins on resistance and immunity. Proceedings Symposium, Michigan State University National Academy of Sciences

Pinkerton, C, Hammer, D I, Bridbord, K, Creason, J P, Kent, J L and Muthy G K (1973) Human milk as a dietary source of lead substances. Trace elements in environmental health. 6 Proceedings of the University of Missouri 6th Annual Conference Trace Substances in Environmental Health. University of Missouri-Columbia

Pinsent, R J F (1973) A monitoring service for environmental health. Trace Elements in Environmental Health **6**, 57-59

Plant J A and Jones, D G (1989) Metallogenic and exploration criteria for buried carbonate-hosted ore deposits - a multidisciplinary study in Eastern England.Institution of Mining and Metallurgy, British Geological Survey, London

Preece, B E (1995a) Potential food safety incidents: protection of the food chain. Cattle Practice **3**, 45-53

Preece, B E (1995b) Lead poisoning in cattle at turnout. Veterinary Record **136**, 475-476

Prevot, A R, Silloc, R and Proute, J (1955) Etude d'un foyer de botulisme bovin du a *Clostridium botulinum.* Annales de l'Institut Pasteur (Microbiologie) **88**, 513-515

Priester, W A and Hayes, H M (1974) Lead poisoning in cattle, horses, cats as reported by the 11 colleges of veterinary medicine in the USA and Canada.
Journal of the American Veterinary Association **35**, 567-569

Pritchard, G C and Lewis, G C (1995) Ryegrass staggers.
Veterinary Record **137**, 471-472

R

Ramsbottom, J (1953) Mushrooms and Toadstools.
Collins, London p 140-153.

Rebesko, B (1958) Toxicity of cabbage to cattle.
Veterinarsk Glasnik **12**, 728-729

Rensburg, S J van, Altenkirk, B (1974) *Claviceps purpurea* ergotism.
Mycotoxins edited by I H F Purchase,
Elsevier Scientific Publishing Co, Amsterdam

Richter, R H and Schlatter, C (1971) Bulletin des Eidgenossischen Gesundheitsamtes Amt. Beil B 3. Cited by Waldron and Stöfen (1974)

Ricketts, S W and Greet, T R C (1984) Thirteen cases of botulism in horses fed big bale silage.
Equine Veterinary Journal **16**, 515-518

Roberts, T A and Collings, D F (1973) An outbreak of type C botulism in broiler chickens.
Avian Diseases **17**, 650-658

Roberts, T A and Gibson, A M (1979) The relevance of Clostrdium botulinum in public health and food poisoning.
Journal of Food Technology **14**, 211-226

Rosenberger, G (1939) Anämie und Hamoglobinurie beim Rinde nach Markstammkohl fütterung.
Deutsche tierärtzliche Wochenshrift **47**, 244-246

Rosenberger, G (1943) Kohlanämie des Rindes.
Deutsche tierärtzliche Wochenschrift **51**, 63-67

Russel, A J F (1967) A note on goitre in lambs grazing rape (*Brassica napus)*.
Animal Production **9**, 131-133

Rylands, J M (1971) *Parascaris equorum* in a 10 month old colt.
Veterinary Record **88**, 587

S

Sauer, R M, Zook, B C and Garner, F M (1970) Demyelinating encephalomyelopathy associated with lead poisoning in non-human primates.
Science **169**, 1091-1093

Schmidtt, H N, Brown, G, Devlin, E L, Larsen A A, McCausland, E D and Saville, J M (1971) Lead poisoning in horses.
Archives of Environmental Health **23**, 185-195

Schofield, F W (1924) Damaged sweet clover: the cause of a new disease in cattle simulating hemorrhagic septicaemia and blackleg.
Journal of the American Veterinary Association **64**, 553-576

Schubert, N (1954) Intoxikationen nach Verfütterung von Weisskohl.
Tierärtzliche Umschau **9**, 179

Sears, J (1988) A review of lead poisoning among the River Thames Mute Swan (*Cygnus olor*) population.
Wildfowl **49**, 151-152

Seawright, A A, Hrdlicka, J and Ng, J C (1983) Heavy metal intoxications in horses. Veterinary Pharmacology and Toxicology Ruckenbusch, Y, Toutain, P-L and Koritz, G D. MTP Press Limited.

Sen, K C (1957) Bulletin No.25 The Nutritive Values of Indian Cattle Foods and the Feeding of Animals.
The Indian Council of Agricultural Research printed for the Manager of Publications, Civil Lines, Delhi.

Shaper, A G (1979) Epidemiology for biochemists.
Philosophical Transactions of the Royal Society **B268**, 127-136

Shapovalov, M (1917) Intoxicating bread.
Phytopathology **7**, 284-286.

Sharma, R P (1993) Immunotoxicity of mycotoxins.
Journal of Dairy Science **76**, 892-897

Sharma, R M and Buck, W B (1975) Ovine abortion and lead toxicity.
Veterinary Toxicology **18**, 186-188

Shaw, P (1992) A preliminary study of the successional changes in vegetation and soil development on unamended fly ash.
Journal of Applied Ecology **29**, 728-736

Shaw, P (1994) Orchid woods and floating islands.
British Wildlife **5**, 149-157

Shearer, G D, Innes, J R M and McDougall, E I (1940) The relationship of copper and lead in the body tissue to the causation of swayback.
Veterinary Journal **96**, 309

Shearer, G D and McDougall, E I (1944) Some observations on swayback disease of lambs.
Journal of Science (Cambridge) **34**, 207-212

Shearer, G D, Innes , J R M and McDougall, I E
Veterinary Journal **96**, 309-322

Shore, S H W, Morgan G and Cross, P J (1984) Lead poisoning in cattle and geese.
Veterinary Record **114**, 126-127

Shortt, H E, McRobert, G R Barnard, T W and Nayar, A S M (1937) Endemic fluorosis in the Madras Presidency.
Indian Journal of medical Research **25**, 553

Siller, W G and Ostler, D C (1961) The histopathology of enterohepatic syndrome of turkey poults. Veterinary Record **73**, 134-135

Simpson, V R, Hunt, A E and French, M C (1979) Chronic lead poisoning in a herd of Mute Swans. Environmental Pollution **18**, 187-202

Smart, J L, Jones T O, Clegg, F G and McMurtry M J (1987) Poultry associated waste type *C botulism* in cattle. Epidemiology and Infection **98**, 73-79

Smith J W, Prince W R and Hamilton, P B (1969) Relationship of aflatoxicoxsis to *Salmonella gallinarum* infection of chickens. Applied Microbiology **18**, 946-947

Smith, R H (1980) Kale poisoning. The brassica anaemia factor. Veterinary Record **107**, 12-15

Stalker, A L and McLean, D L (1957) The incidence of oedema in young guinea pigs. Journal of the Animal Technicians Association **8**, 18-20

Stamp, J T and Stewart, J (1953) Haemolytic anaemia with jaundice in sheep. Journal of Comparative Pathology **63**, 48-52

Standley, W F (1924) An unusual case of lead poisoning in cattle. Veterinary Journal **80**, 87-88

Stanley, P I and Bunyan, P J (1979) Hazards to geese and other wild life from the use of dieldrin, chlorfenvinphos and carbophenothion as wheat seed treatments. Proceedings of the Royal Society of London **B205**, 31-45

Staples, E L J (1955) Lead poisoning in the dog. New Zealand Veterinary Journal **3**, 39

Stewart, W L (1932) Swingback (ataxia) in lambs. Veterinary Journal **88**, 133-137

Stewart, W L and Allcroft, R (1956) Lameness and poor thriving in lambs on farms in old lead mining areas. Veterinary Record **68**, 723-728

Suttle, N F (1986) Copper deficiency in ruminants; recent developments. Veterinary Record **119**, 519-522

Suttle, N F (1998) Swayback warning. Veterinary Record **142,** 342

Suttle, N F, Abrahams, P and Thornton, I (1984) The role of soil X dietary sulphur interaction in the impairment of copper absorption by ingested soil in sheep. Journal of agricultural Science, Cambridge **103,** 81-86

Swaine, D J (1969) The Trace Element Content of Soils. Tech Communication No.48. Commonwealth Agricultural Bureau, Slough, UK

T

Tataruch, F (1995) Red deer antlers as biomonitors for lead contamination. Bulletin of Environmental Contamination and Toxicology **55,** 332-337

Taylor, D (1968) The interpretation of lead and zinc in stream sediment anomalies related to contamination and mineralisation in the United Kingdom. PhD thesis, University of London

Theiler, A, Viljoen, P R, Green, H H, du Toit, P J, Meier, H and Robinson, E M (1927) 12th Annual Report of the Director of Veterinary Research, Union of South Africa page 821

Thomson, B, Roughan, J and Walters, E D (1972) Lead and cadmium content of some vegetable foodstuffs. Journal of Science, Food and Agriculture **23,** 1493-1496

Thornton, I and Kershaw, G F and Davies, M K (1972) An investigation into copper deficiency in cattle in the Southern Pennines. Journal of Agricultural Science (Cambridge) **78,** 157-163

Thornton, I (1980) Inorganic Pollution and Agriculture. Ministry of Agriculture, Fisheries and Food Reference Book 326, p 105-125. HMSO, London

Thornton, I and Abrahams, P (1983) Soil ingestion, a major pathway of heavy metals. Science of the Total Environment **28,** 287-294

Thornton, I and Webb, J S (1970) Geochemical reconnaissance and the detection of trace element disorders in animals. Trace Element Metabolism in Animals. C F Mills, Livingstone, London

Thornton, I, Kinniburgh, D G, Clegg, F G, Lewis, G, Barltrop, D and Strehlow, C (1988) Lead uptake in bovine blood and faeces in relation to lead pollution in agricultural soil. (Unpublished results)

Thornton, R (1964) An examination of ergot in relation to ryegrass staggers. New Zealand Veterinary Journal **12,** 13-16

Todd, J R (1962) A knackery survey of lead poisoning incidence in Northern Ireland. Veterinary Record **74,** 116-118

Towers, K G (1954) Chronic fluorine poisoning associated with industry. Veterinary Record **66,** 355-358

Tulasne, L R (1853) Mémoires sur l'ergot des Glumacees. Annales Science Naturelle **3,** Series 20

U

U Nagaharu (1934) Cytogenetical studies on hybrids of *Brassicae campestris* and *B.oleracea* L. Japanese Journal of Genetics **9**(3), 159-160

V

Van Middlesworth, L (1958) Iodine 131 fallout in bovine foetus. Science **128**, 597-598

Verhhoeff, J, van der Wende, T and Schotman, A J H (1981) Lead content from cattle fed roughage cut from motorway verges. Tijdschrift voor Diergeneeskunde **106**, 917-923

Veterinary Medicines Directorate (1996) Annual Report on the Surveillance of Veterinary Residues in 1955. MAFF, London

Virtanen, A I, Kreula, M and Kiesvaara, M (1963) Investigations into the alleged goitrogenic properties of cow's milk. Zeitschrift fur Ernährungswissenschaft Suppl **3**, 23-37

Vishwanathan, G B (1934) Annual Report VIO, Madras. page 35 Cited by Brahm Dutt (1972) in Deficiency Diseases of Livestock, Indian Council of Agricultural Research, New Delhi.

W

Wachstein, M (1949) Studies on inclusion bodies. I. Acid fastness of nuclear inclusion bodies that are induced by ingestion of lead and bismuth. American Journal of Clinical Pathology **19**, 608-614

Waldron, H A and Stöfen, D (1974) Sub-clinical lead poisoning. Academic Press, New York and London

Wainman, F W, Dewey, P J S and Brewer, A C (1984) Feeding Stuffs Evaluation Unit, Fourth Report, Rowett Research Institute, Aberdeen

Ward, N I, Bryce-Smith D, Mindski, M and Matthews, W B (1985) Multiple sclerosis: a multi-element survey. Biological Trace Elements Research **7**, 153-159

Wardrope, D D and Graham, J (1982) Lead mine waste: hazards to Livestock. Veterinary Record **111**, 457-459

Warren, H V, Delavaull, R I and Cross, C H (1967) Possible correlations between geology and some disease pathways. Annals of the New York Academy of Sciences **136**, 696

Webb, J S (1964) Geochemistry and life. New Scientist **23**, 504

Webb, J S, Thornton, I and Fletcher, K (1966) Seleniferous soils in parts of England and Wales. Nature, London **221**, 327

Webb, J S, Thornton, I and Fletcher, K (1968) Geochemical reconnaissance and hypocuprosis. Nature, London **217**, 1010

Webb, J S, Thornton, I and Nichol, I (1971) The agricultural significance of regional geochemical reconnaissance in the United Kingdom. Trace Elements in Soils and Crops MAFF Technical Bulletin No **21** London, HMSO

Webb, J S, Thornton, I, Thompson, M, Howarth, R J and Lowenstein, P L (1978) The Wolfson Geochemical Atlas of England and Wales. Clarendon Press, Oxford

Wells, H E (1937) "Swayback" in lambs. Derbyshire Farmer **17**, 280

Wells, R E, Slocombe, R F and Trapp, A L (1982) Acute toxicosis in budgerigars (*Melopsitacus undulatus*) caused by pyrolysis products from heated PTFE. A case study. American Journal of Veterinary Research **43** (7), 1238-1242

Wells, R E (1983) Fatal toxicosis in pet birds caused by an overheated cooking pan lined with PTFE.
Journal of the American Veterinary Association **182** (11), 1284-1290

Whitaker, D A (1997) Copper toxicity in sheep.
Veterinary Record **141**, 556

Wild, M S, Eastwood, I W E and Newman, A P (1984) Background distribution of some heavy metals in soils of North East Derbyshire, England.
Sheffield City Polytechnic Research Report (NED Cont Surv) 1/84

Wild, M S and Eastwood, I W E (1992) Soil contamination and smelting sites. Boles and Smelting Seminar 15-17 May 1992.
Historical Metallurgy Society

Williams, H L, Hill, R and Alderman, G (1965) The effects of feeding kale to breeding ewes.
British Veterinary Journal **121**, 2-17

Willoughby, R A, McDonald, I, McSherry, B J (1972) Lead and zinc poisoning and the interaction between Pb and Zn poisoning in the foal.
Canadian Journal of Comparative Medicine **36**, 348-349

Wilson, G L, Osweiler, G D and Garner, H E (1979) Experimental induction and review of lead toxicity in a Shetland pony.
Journal of Equine Medicine and Surgery **3**, 386-390

Wilson, M R and Lewis, G (1963) Lead poisoning in dogs.
Veterinary Record **75**, 787-791

Winter, O B, Robinson, H M, Lamb W F and Miller, E J (1935) Determination of lead. A modification of the Fischer Leopodi method.
Industrial Engineering Chemistry Analytical Edition **7**, 205-271

Wolff, E von (1895) Landwirtschaftliche Fütterungslehre.
6th Edition, Gurney and Jackson, London

Wolkers, H, Wensing, T, and Groot-Bruinderink, G W (1994) Heavy metal contamination in the organs of red deer (*Cervus elaphus*) and wild boar (Sus scrofa) and the effects on some trace elements. Science of the Environment **144**, 191-199

Woods, A J (1965) The persistence of lead paint. State Veterinary Journal **20**, 103-107

Y

Yeoman, G H (1983) Copper in relation to lamb losses. Veterinary Record **112**, 547

Z

Zook, B C, Carpenter, J L and Leeds, E B (1969) Lead poisoning in dogs. Journal of the American Veterinary Medical Association **155**, 1329

Zook, B C, Sauer, R M and Garner, F M (1970) Lead poisoning in fruit bats. Journal of the American Veterinary Medical Association **157**, 691

Zook, B C, Carpenter, J L and Roberts, R M (1972) Lead poisoning in dogs: occurrence, source, clinical pathology and electroencephalography. American Journal of Veterinary Research **33**, 891