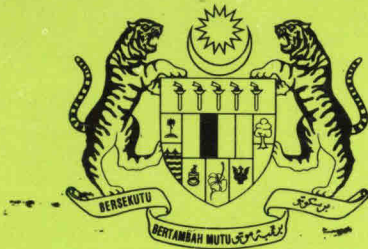


THE ACID TRAIL I: RIDING THE ILL
WINDS OF SULFUR



MALAYSIA



JABATAN ALAM SEKITAR

Department of Environment

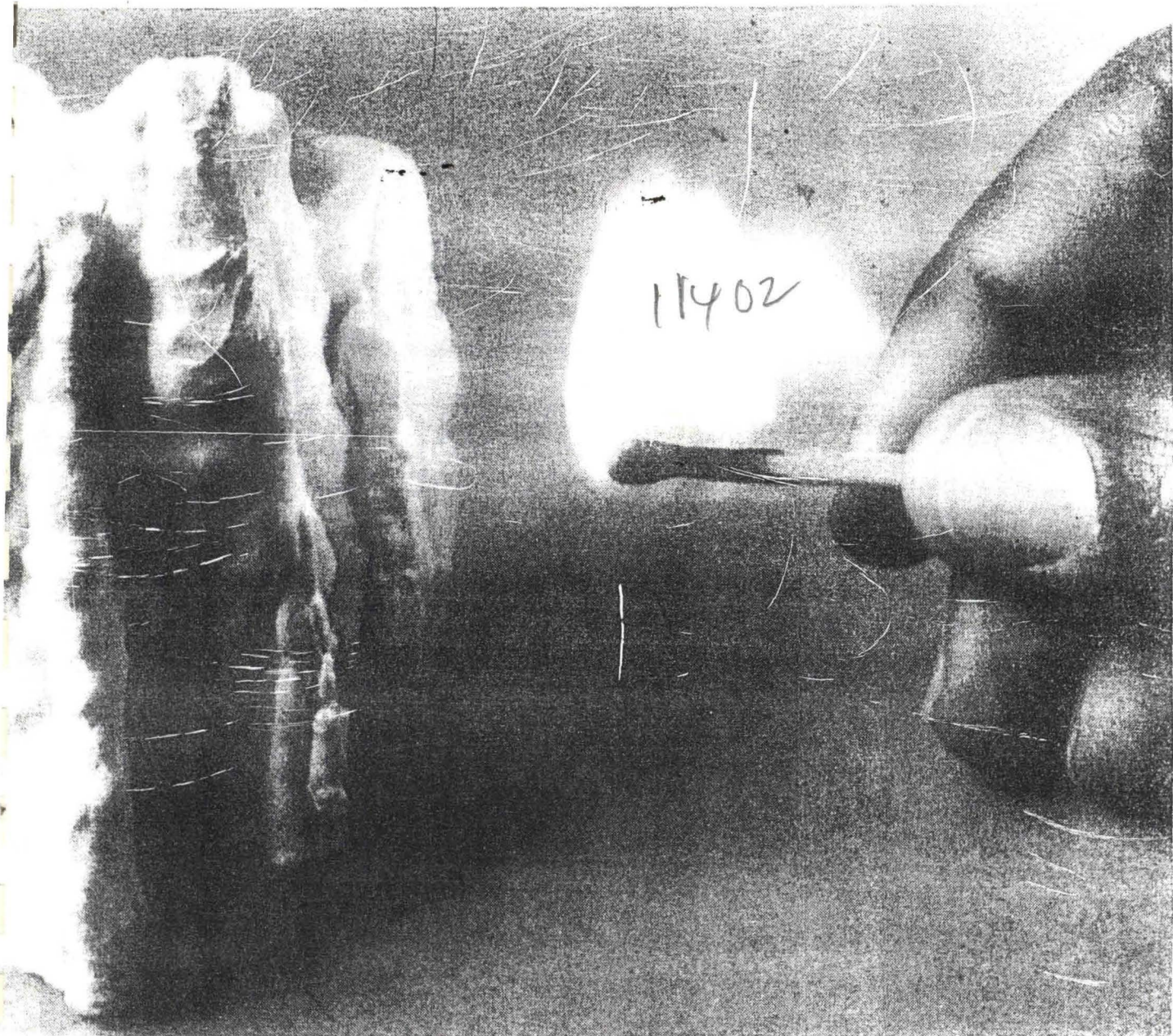
**.25 KEMENTERIAN SAINS, TEKNOLOGI DAN ALAM SEKITAR
MALAYSIA**

HAYES, Paul G.

The Acid trail I : riding the ill winds of
sulfur

661.25/HAY

RSN=00011402



The trail that leads to acid rain starts when sulfur burns.



The Acid Trail



CLASS NO:

ACCESSION NO: 11455

DATE: 2/11/88

A reprint of a series of articles by Journal Science Reporter Paul G. Hayes that appeared in The Milwaukee Journal December 23 through December 28, 1984.

The Milwaukee Journal



DEPARTMENT OF THE ENVIRONMENT

Nineteenth Progress Report
of the Standing
Technical Committee on
Synthetic Detergents

661.187.
76(047)
NIN

LONDON

HER MAJESTY'S STATIONERY OFFICE

75p net

Scotland. Department of Environment
NINETEENTH progress report of the standing
technical committee on systhetic detergents
661.187.76(047)/NIN

RSN=00002814

PERPUSTAKAAN JAS



100003084

PERPUSTAKAAN
JABATAN ALAM SEKITAR

2814

DEPARTMENT OF THE ENVIRONMENT

Nineteenth Progress Report
of the Standing
Technical Committee on
Synthetic Detergents



CLASS NO:
ACCESSION NO: 8223
DATE: 17/1/87

LONDON
HER MAJESTY'S STATIONERY OFFICE

© Crown copyright 1979

First published 1979

ISBN 0 11 751134 X

The Standing Technical Committee on Synthetic Detergents was appointed by the Minister of Housing and Local Government, in consultation with the Secretary of State for Scotland on 9th January 1957. The Committee's terms of reference are as follows:—

To keep under review any difficulties or risks of difficulties arising in sewage treatment works, natural waters and water supply as the result of the use of surfactants and associated products;

To advise on the potential effects upon the use of surfactants and associated products in the United Kingdom of any action proposed by international agencies;

To encourage and assist the co-ordination of appropriate research by manufacturers of detergents and intermediate materials and related products;

To recommend as necessary, the carrying out of suitable research;

To report progress at intervals of not more than 1 year.

The members who served on the Committee in the period covered by this report were:

D H A Price, CBE, BSc, CChem, FRIC, CEng, FICHEM, FIWES,
PPInstWPC (Chairman)

G Ainsworth, BSc, PPInstWPC (Dip), FIPHE, FIWES

G K Ashforth, BSc, PhD, CEng, MICHEM

P I Brittain, BSc

G E Eden, BSc, CChem, FRIC, FInstWPC, FIWES

J K Foreman, DSc, CChem, FRIC (resigned September 1977)

H R Galleymore, MA, Hon DCL, CChem, FRIC, CEng, FICHEM

P H Garnett, CChem, FRIC, FIWES, MInstWPC, (from April 1977)

N Harkness, BSc, PhD, FInstWPC

J Leicester, OBE, CEng, FICHEM, AIMarE, CChem, FRIC,
FTI, FGCL

R Lloyd, BSc, FIBiol, FZS

W McCamley, BSc

G K Matthew, MBE, MD, BChir, MSCM, DTMCH (from March
1978)

T W Raven, BSc, CChem, FRIC, MInstWPC, FIWES

J R Reid, MB, ChB, DIH, DPH, FRCS (Resigned November 1977)

E L Shepherd, BSc

A Taylor, MPS

E Windle Taylor, CBE, MA, MD, DPH, FRCPath, Hon FIPHE,
FIWES

G A Truesdale, BSc, MIWES, FIPHE, FInstWPC

S T Walter, BSc, PhD, CChem, FRIC

T Waldmeyer, BSc, CChem, FRIC, MInstWPC, FIPHE

L B Wood, BSc, CChem, FRIC, FIPHE, MInstWPC

R Wood, BSc, PhD, CChem, FRIC (from November 1977)

J L Vossler, BSc, CChem, MRIC (Secretary)

NOTE: Members are appointed to the Committee by the Secretary of State with the approval of the Secretary of State for Scotland, and in the case of members with industrial affiliations, after consultations with the Confederation of British Industry. Members serve in an individual capacity. Further details concerning the membership are recorded in Appendix A1.

NINETEENTH PROGRESS REPORT
OF THE STANDING TECHNICAL COMMITTEE
ON SYNTHETIC DETERGENTS

TABLE OF CONTENTS

	<i>Paragraph</i>
Membership	1
Review of the Position	2
Surfactant Loading in Crude Sewage	3
Consumption Trends	4
Technical Sub-Committee	5
Research	6
Phosphates	7
Summary	8

Appendices

Membership

- A1 Main Committee
- A2 Technical Sub-Committee

Technical Data

- B Anglian Water Authority — Rivers
- C Thames Water Authority — Rivers
- D Data on Production for UK Consumption

NINETEENTH PROGRESS REPORT
OF THE STANDING TECHNICAL COMMITTEE
ON SYNTHETIC DETERGENTS

To: The Right Hon Peter Shore, M.P.
Secretary of State for the Environment

Sir,

We have the honour to submit to you our Nineteenth Progress Report. In the period covered by the Report, the Committee has met on three occasions, the Technical Sub-Committee once and the Analytical Working Group on four occasions.

The Committee are grateful to the Water Authorities and other bodies for their helpful co-operation in supplying analytical and other data without which it would not be possible to review the position.

1. MEMBERSHIP

1.1 Full details of the Membership of the Committee and its associated subsidiary committees may be found in Appendices A1 and A2.

1.2 Dr J K Foreman resigned from the Committee in September 1977 on taking up other duties within the Department of Industry. We thank him for his invaluable services to your Committee for many years and also for his able Chairmanship of the Technical Sub-Committee. Dr R Wood (Deputy Director, Resources, of the Laboratory of the Government Chemist) of the same Department was appointed to the Committee in November 1977 to fill the vacancy created by the resignation of Dr J K Foreman. Dr Wood has taken over the Chairmanship of the Technical Sub-Committee.

1.3 We would also like to record our appreciation of the services of Dr J R Reid of the Department of Health and Social Security to your Committee and of Mr I Forsyth, of BP Oil Ltd, to the Technical Sub-Committee. The vacancies created by these changes have been filled respectively by Dr G K Matthew and Miss M McCaw (also of BP Oil Ltd.).

2. REVIEW OF THE POSITION

In the period of monitoring under review, no difficulties attributable to surface active agents were reported either in the operation of sewage treatment and water supply plants or in rivers. In view of this, we do not propose to reproduce in this report all of the data made available to the Committee, but rather to present in Appendices B and C, selected data for areas of particular interest which will enable continuity to be maintained over the period 1975 to 1977.

3. SURFACTANT LOADING IN CRUDE SEWAGE

The Eighteenth Report made reference to a survey of certain treatment works in the area of the Thames Water Authority which suggested that over

the period 1972 to 1976 there had been a decrease in the per capita load of anionic surfactant in crude sewage which was not necessarily accompanied by a change in the load arising from the Biochemical Oxygen Demand (BOD). We have sought the further co-operation of the Thames Water Authority and also of the other Water Authorities represented on your Committee to investigate more fully the reasons for these changes and to determine whether they were occurring in other areas of the United Kingdom. Changes in the concentration of anionic surfactant and BOD noted in Stevenage crude sewage were also investigated.

The appropriate techniques of statistical analysis have been applied to the data to determine whether or not there were any significant trends to be established from the information. Whilst it is possible to identify significant changes at a number of sewage treatment works at the 95% level of probability, the reasons for these changes have not been found. Your committee will continue investigations into the matter.

4. CONSUMPTION TRENDS

The data on production for UK consumption for 1977 are presented in Appendix D. The quantities attributable to ancillary washing powders and surface cleaning materials have been deducted from the total tonnages for earlier years to enable comparisons to be made with the 1977 data. These products are mainly based on chlorine bleaches and are not therefore considered to be relevant.

It will be evident from the data the changes are minimal and likely to be within the error of the estimations.

5. TECHNICAL SUB-COMMITTEE

5.1 Members of this Committee who form the Analytical Working Group have continued work on the preparation of analytical methods for the determination of surfactants in crude sewage, sewage sludge, effluents and natural waters as a contribution to the series of analytical methods to be published by Her Majesty's Stationery Office on behalf of the joint National Water Council/Department of the Environment Standing Committee of Analysts.

5.2 The "Guidelines for Data Presentation" for use in connection with the Voluntary Notification Scheme, prepared by the joint Technical Sub-Committee/Soap and Detergent Industry Association working party, under the chairmanship of Mr C R Pearson, have now been published and may be obtained through the Secretary of your Committee.

6. RESEARCH

6.1 The Stevenage Laboratory of the Water Research Centre (WRC) has continued to carry out research under contract on behalf of the Committee.

6.2 The concentrations of anionic and nonionic surfactants in the River Lee at Lemsford have continued to be monitored.

These have remained low with a mean concentration of anionic surfactant of 0.20 mg/l and of nonionic surfactant 0.04 mg/l, compared with mean values for the corresponding period in 1976/1977 of 0.26 mg/l and 0.07 mg/l respectively.

6.3 The performance of the two biological filters treating Stevenage sewage has shown that the mean removals of anionic and nonionic surfactants has been 97.5 and 95.5 per cent respectively. The concentration ranges and averages in the sewage were as follows:

	Concentration (mg/l)	
	Range	Average
Anionic	17.8-26.4	23.0
Nonionic	0.8- 3.0	1.8

6.4 The following table shows the changes in the mean annual concentrations of some determinands in Stevenage sewage:—

**TABLE 1. CONCENTRATION OF SOME DETERMINANDS
IN STEVENAGE SEWAGE**

Year	BOD	NH ₃ as N	Anionic detergent (as Manoxol OT)
	mg/l		
1971	278	51.0	28.9
1972	281	49.7	31.3
1973	295	51.2	31.0
1974	267	44.9	27.6
1975	305	47.5	26.7
1976	292	48.5	28.0
1977	257	50.1	23.0

The concentration of anionic surfactants in the sewage in 1977 is low but it is not possible to say whether or not this is significant. A decrease in the concentration of nonionic surfactants was noted from 2.3 mg/l in 1976 to 1.8 mg/l in 1977.

6.5 Experimental work has been completed on the comparisons of the removal of surfactants by activated sludge grown on phosphate deficient and phosphate enriched EEC synthetic sewage. Tetrapropylene benzene sulphonate was the only surfactant which did not show an increase in the proportion removed when adequate phosphate was present, but the removal was low and highly variable.

This work has also shown that the lower removal of alkyl phenol ethoxylates at 10°C compared with 20°C was not caused by a deficiency of phosphate nutrient but was due to the effect of temperature.

6.6 The following table presents the results of experiments designed to determine the reproducibility of the EEC Husmann and WRC POROUS-POT methods:—

**TABLE 2. REMOVAL OF VARIOUS SURFACTANTS
(MEAN VALUES FROM 4 VESSELS OF EACH TYPE)**

Surfactant	Percentage removed	
	EEC units	WRC units
SH30	99 (± 0)	99 (± 0.5)
JN	96 (± 0.6)	96 (± 1.0)
NP10	87 (± 1.9)	84 (± 1.4)
JN+TBS 3:1	86 (± 0.8)	83 (± 5.0)
JN+TBS 3:2	78 (± 1.7)	—*
TBS	28 (± 1.4)	35 (± 2.0)

*Not tested.

Values in brackets are actual standard deviations.

JN=Dobane JN sulphonate; TBS=tetrapropylene benzene sulphonate;

NP10=Marlophen (alkylphenol ethoxylate)

SH30=Nonidet SH30 (alcohol ethoxylate)

The results indicate that for surfactants biodegraded to at least 80%, a test carried out by either method could be expected to produce a reliable result. For the less easily degraded materials the value of the relative standard deviations (RSD) of the mean results from 4 vessels were low but the RSD values for the mean of each unit were much higher (up to 33%), so that to obtain a reliable result a number of vessels should be used.

6.7 The draft EEC directive on the biodegradability of nonionic surfactants incorporates both the Husmann and WRC Porous-Pot methods as the test procedures and work has been carried out to establish the nature and size of the bacterial inoculum required to obtain optimum results in both procedures. The draft procedure requires the addition of 1 ml of sewage, sewage effluent or soil extract per litre but this did not give any advantage presumably because the treatment units were inoculated by aerosols from nearby activated sludge plants treating domestic sewage. The acclimatization period in the case of a readily biodegradable anionic surfactant in the test was greatly reduced by adding 2.5 g activated sludge per litre but not for a poorly degraded material. It was found that there were no adverse effects upon the test when the synthetic sewage used was prepared daily by dilution of a concentrated stock solution made up weekly and stored at 1°C. It was found necessary to collect 24 hourly composite samples for analysis because of hourly variations in quality, particularly when poorly degraded surfactants were being studied.

6.8 The assessment of the biodegradability of compounds, for which there are no specific analytical methods, has to be carried out using a general test

such as Total Organic Carbon (TOC) and experimental work has been directed at the evaluation of the use of changes in TOC as an indicator of biodegradability using "soft" (Dobane JN sulphonate) and "hard" (tetrapropylene benzene sulphonate) surfactants in the EEC screening and confirmatory test procedures. In the screening ("die-away") test the proportion of the "soft" material removed, varied considerably from test to test, (39–63%) as assessed by TOC measurements; the proportion removed as assessed by the methylene blue active substances (MBAS) test was much higher and more consistent. With the "hard" material, up to 4% of the TOC disappeared in contrast to 23% of MBAS. The following table summarises the work carried out so far:—

TABLE 3. BIODEGRADABILITY OF TWO ANIONIC SURFACTANTS ASSESSED BY MBAS AND TOC

Anionic Surfactant	Percentage removed			
	Die-away test		Confirmatory test	
	MBAS	TOC	MBAS	TOC
JN	97	47		
	90	39	93	76
	95	45	96	87
	93	53	97	82
	92	55		
Av.	96	63		
	94	50	95	82
TBS			70	69
	23	0	58	80
	23	4	74	46
Av.	23	2	67	65

6.9 Experiments have been carried out to attempt to identify the intermediate products of biodegradation of Dobane JN sulphonate subjected to the EEC "die-away" (screening) test. Some of the organic carbon remaining has been identified by concentrating the sample, desulphonating, and then carrying out an analysis on the product using gas liquid chromatography.

In the samples taken up to Day 8, 26 identifiable hydrocarbons were found, these being formed from the original alkylbenzenesulphonates by desulphonation. After 13 days, when 84% removal of MBAS was achieved, most of these compounds had disappeared and a series of 8 new compounds were identified. These were alkyl derivatives of indanone and tetralone formed by desulphonation and ring closure of Dobane JN derivatives with partially oxidised side chains. Other derivatives were still present in the reaction products at concentrations in the range 200–500 $\mu\text{g/l}$ after 44 days.

Another experiment was conducted using the Husmann technique and the same surfactant. The results were much more variable and the concentrations

of the 8 substances (indanones and tetralones) were found to be much lower. It is intended to make further analyses when the plants have been running for a much longer period.

6.10 An automated method for the determination of nonionic surfactants in samples from "die-away" tests using ammonium cobaltthiocyanate has been established. Conventional equipment has been modified in respect of the phase separation and the flow cell to improve the separation of the aqueous and chloroform phases and to prevent the accumulation of fine air bubbles which give spurious absorbances.

Nonionic surfactants in the concentration range 1 to 10 mg/l can be accommodated with a standard deviation of 0.2 mg/l at the upper concentration value. The method is not particularly rapid with a sampling rate of 3 samples per hour and 18 to 20 samples per day, but it is faster and less tedious than manual methods. It cannot in its present form be applied to sewage samples because of emulsion formation.

7. PHOSPHATES

7.1 During the period under review the attention of your Committee was drawn to various reports in the national and technical press concerning the deterioration in the condition of the Norfolk Broads. We are pleased to note that your Department is jointly funding with the Anglian Water Authority, a 3 year programme which will study eutrophication of the Norfolk Broads and that a steering committee is to be formed on which your Committee will be represented. We understand that additionally the Anglian Water Authority is to carry out a programme of work on the removal of phosphorus from the final effluent of one of the sewage treatment works which discharges its effluent into one of the Broads.

7.2 A report⁽¹⁾ entitled "Phosphorus: A Resource for UK Agriculture" was brought to the attention of members of your Committee because reference was made to the need for detergent phosphates to be replaced by other materials. Substitution of detergent phosphate continues to be the subject of much debate and indeed we have in several previous reports⁽²⁾ discussed the matter in detail and could find no justification for such a replacement. Whilst we remain of the same opinion on both technical and economic grounds, we shall continue to keep this subject under review.

8. SUMMARY

8.1 In the period under review there were no reported instances of problems arising from the use of surfactants in the United Kingdom in either sewage treatment or rivers, the use of river water and the supply of potable water drawn from rivers.

⁽¹⁾Phosphorus: A Resource for UK Agriculture, Centre for Agricultural Strategy, University of Reading CAS Report No 2. February 1978.

⁽²⁾Reports of the Standing Technical Committee on Synthetic Detergents Nos X, XI, XII, XIII, XV and XVIII. London HMSO.

8.2 In general, few of the reported decreases in anionic surfactant concentrations in crude sewage have any significance statistically at the 95% level. No reasons for the observed decreases which are significant have yet been found.

8.3 Experimental work on the removal of both anionic and nonionic surfactants in the OECD and WRC POROUS POT tests has shown that if the surfactant is biodegraded to at least 80%, then the results obtained in either test would be acceptable in terms of the EEC Directives. To obtain reliable results for surfactants of low and not readily biodegradable material, a number of tests should be carried out by either method.

8.4 An automated analytical method has been developed for the determination of nonionic surfactants, using ammonium cobalthiocyanate, in samples of river water and effluents but not in sewage.

8.5 Your Committee remains of the opinion that in the foreseeable future in the United Kingdom there will be no necessity to introduce phosphate substitutes in detergent formulations but will nevertheless continue to investigate this subject. Your Committee will continue to take an active interest in the research work and other studies which are being carried out by various bodies on certain of the Norfolk Broads in an attempt to establish the cause of the change in the ecology which has been noted.

We have the honour to be, Sir
Your obedient Servants,

D H A PRICE (*Chairman*)

G AINSWORTH

G K ASHFORTH

P I BRITAIN

G E EDEN

J K FOREMAN

H R GALLEYMORE

P H GARNETT

N HARKNESS

J LEICESTER

R LLOYD

G K MATTHEW

W MCCAMLEY

T W RAVEN

J R REID

E L SHEPHERD

A TAYLOR

E WINDLE TAYLOR

G A TRUESDALE

T WALDMEYER

S T WALTER

L B WOOD

R WOOD

J. L. VOSSER
Secretary

31 December 1978

APPENDIX A1

Membership of the Main Committee

NAME	OFFICIAL APPOINTMENT
Mr D H A Price (<i>Chairman</i>)	Consultant Chemist.
Mr G Ainsworth	Director of Scientific Services, North West Water Authority.
Dr G K Ashforth	Professional Relations Manager, Procter and Gamble Ltd.
Mr P I Brittain	Technical Director, Brent Chemicals International Ltd.
Mr G E Eden	Assistant Director, Water Research Centre, Stevenage Laboratory.
Dr J K Foreman	Deputy Government Chemist, Laboratory of the Government Chemist.
Dr H R Galleymore	Retired.
Mr P H Garnett	Superintending Chemist, Chemical Division of Water Engineering, Department of the Environment.
Dr N Harkness	Co-ordinator (Treatment Processes) Severn-Trent Water Authority.
Mr J Leicester	Chairman of Effluent and Water Advisory Committee. Consultant.
Mr R Lloyd	Deputy Chief Officer, Salmon and Freshwater Fisheries Laboratory, Ministry of Agriculture Fisheries and Food.
Mr W McCamley	Chief Inspector HM Industrial Pollution Inspectorate for Scotland, Scottish Development Department.
Dr G K Matthew	Principal Medical Officer, Department of Health and Social Security.
Mr T W Raven	Assistant Director of Operations (Scientific Services) Yorkshire Water Authority.
Dr J R Reid	Senior Medical Officer, Department of Health and Social Security.
Mr E L Shepherd	Technical Service Manager, Shell Chemicals UK Ltd.
Mr A Taylor	Corporate Technical Manager, Albright and Wilson Ltd.
Dr E Windle Taylor	Retired/Consultant.

Mr G A Truesdale	Partner, Balfours, Consulting Engineers.
Dr S T Walter	Quality & Development Controller, Lever Brothers Ltd.
Mr T Waldmeyer	Retired/Consultant.
Mr L B Wood	Assistant Director of Scientific Services (Pollution Control) Thames Water Authority.
Dr R Wood	Deputy Director (Resources), Laboratory of the Government Chemist.
Mr J L Vosser (<i>Secretary</i>)	Department of the Environment.

APPENDIX A2

Technical Sub-Committee, Standing Technical Committee on Synthetic Detergents

J K Foreman, DSc, CChem, FRIC (*Chairman* to September 1977), Laboratory of the Government Chemist, Department of Industry

G K Ashforth, BSc, PhD, CEng MIChemE, Proctor and Gamble Ltd

P I Brittain, BSc, Brent Chemicals International Ltd

D Burns, BSc, CChem, FRIC, Scientific Branch, Greater London Council

I Forsyth, BSc, *BP Oil Ltd

P A Gilbert, BSc, PhD, CChem, MRIC, Unilever Research, Port Sunlight Laboratory

E Johnston BSc, Albright and Wilson Ltd,

R Lloyd, BSc, FIBiol, FZS, Salmon and Freshwater Fisheries Laboratory, Ministry of Agriculture, Fisheries and Food

Miss M McCaw, BSc, *BP Oil Ltd

H A Painter, BSc, PhD, CChem, MRIC, *Water Research Centre, Stevenage

Miss S J Patterson, BSc, PhD, CChem, FRIC, MInstWPC, *South West Water Authority

C R Pearson, MA, Imperial Chemical Industries Ltd

A T Pugh, CChem, FRIC, *Lankro Chemicals Ltd

M Purvis, BSc, MSc, PhD, *Finham Regional Laboratory, Severn-Trent Water Authority

C C Scott, BSc, CChem, MRIC, *Laboratory of the Government Chemist, Department of Industry

P A H Sperring, BSc, CChem, FRIC, FRSH, MIWES, Thames Water Authority

A H Turner, MA, BSc, DPhil, Shell Research Ltd

R Wood, BSc, PhD, CChem, FRIC (*Chairman* from November 1977), Laboratory of the Government Chemist, Department of Industry

J L Vosser, BSc, CChem, MRIC (*Secretary*), *Department of the Environment

Other members of the staff of the Water Research Centre (Stevenage Laboratory), of the Laboratory of the Government Chemist, MAFF and DHSS and of other participating laboratories attend meetings as required.

Note: *denotes membership of the Analytical Working Group.

APPENDIX B

ANGLIAN WATER AUTHORITY
BEDFORD WATER DIVISION
RIVER GREAT OUSE

Quality Characteristics 1977

Sample Pt.	Temperature °C		Ammoniacal Nitrogen mg/l		Nitrate Nitrogen mg/l		BOD mg/l		Phosphate as Phosphorus mg/l		Anionic Detergent mg/l*		Chlorophyll-a mg/m ³		Dissolved Oxygen % of saturation		Flow at Bedford Bridge m ³ × 10 ³ /d
	SB	BWW	SB	BWW	SB	BWW	SB	BWW	SB	BWW	SB	BWW	SB	BWW	SB	BWW	
MONTH																	
January	5	4	0.3	0.2	19.1	19.7	2.8	2.1	0.2	0.2	0.06	0.08	5	6	90	93	2675
February	6	5	0.2	0.1	15.2	14.8	2.9	3.1	0.2	0.1	0.05	0.06	8	6	82	80	4158
March	6	7	0.1	0.1	11.8	12.3	4.0	1.9	0.3	0.3	0.04	0.06	9	8	85	97	1886
April	8	9	0.1	<0.1	9.9	10.7	2.4	1.6	0.5	0.4	0.09	0.06	16	11	105	105	643
May	12	13	0.2	<0.1	7.9	7.8	2.7	3.1	0.8	0.5	0.06	0.06	18	29	103	101	546
June	13	14	0.2	<0.1	7.9	7.1	3.2	3.3	0.9	0.6	0.09	0.07	16	45	89	94	461
July	18	17	0.1	<0.1	7.7	6.8	2.6	3.9	1.3	0.7	0.08	0.07	18	46	97	102	198
August	16	17	0.2	<0.1	6.2	6.3	2.4	2.2	1.1	0.9	0.09	0.06	7	10	84	73	528
September	14	14	0.1	<0.1	8.0	7.1	1.9	1.5	1.4	0.8	0.07	0.05	8	5	94	83	275
October	12	12	0.1	0.1	8.7	8.5	1.2	1.0	1.7	1.4	0.06	0.05	7	5	83	84	210
November	7	7	0.4	0.1	8.3	7.9	2.7	2.3	1.5	1.3	0.07	0.08	5	5	89	86	306
December	5	6	0.3	0.3	10.1	10.1	3.0	2.8	0.8	0.6	0.06	0.07	10	9	87	91	2042

Notes: SB: Sherington Bridge; located about 1.6 km. f Bedford Water Works discharge.

BWW: Bedford Water Works—Clapham Intakes.

* Anionic surfactant as Manoxol OT.

APPENDIX B
ANGLIAN WATER AUTHORITY
ANIONIC SURFACTANT AND BORON CONCENTRATIONS
IN SELECTED RIVERS

Period; 1 April 1976 to 31 March 1977

RIVER/SAMPLING POINT	ANIONIC SURFACTANT mg/l (Manoxol OT)				BORON mg/l			
	No of Samples	Min	Max	Mean	No of Samples	Min	Max	Mean
STOUR								
Wixoe Intake	56	< 0.02	0.70	0.09	8	0.07	0.48	0.27
Langham Intake	55	< 0.02	0.15	0.05	10	< 0.1	0.46	0.22
BLACKWATER								
Langford Intake	54	< 0.02	0.19	0.06	12	< 0.05	0.40	0.20
CHELMER								
Langford Intake	53	< 0.02	0.20	0.05	10	< 0.01	0.37	0.15
Springfield Mill	160	< 0.02	0.20	0.04	13	< 0.01	0.42	0.16
MARDYKE								
A13 Road Bridge	44	< 0.02	0.31	0.11	11	< 0.10	1.60	0.56
GREAT OUSE								
Brackley A422 Road Bridge ..	12	0.02	0.05	0.03	5	0.11	0.53	0.27
Old Stratford A5 Road Bridge ..	14	< 0.02	0.06	0.03	11	0.09	0.47	0.24
Newport Pagnall A422 Road Bridge ..	18	0.02	0.15	0.08	15	0.14	1.08	0.53
Kempston	20	0.02	0.11	0.07	13	0.18	0.85	0.53
Roxton	4	0.10	0.17	0.14	3	1.05	1.64	1.26
St. Neots A45 Road Bridge ..	16	0.02	0.17	0.09	23	0.15	1.13	0.63
Offord Cluny Intake	23	0.02	0.17	0.09	30	0.10	1.15	0.69
Earith A1123 Road Bridge	56	< 0.02	0.19	0.07	14	0.16	0.98	0.62
(1) Adelaide B1382 Road Bridge ..	18	0.04	0.14	0.09	9	0.21	0.72	0.49
(2) Hilgay Bridge Ten Mile Bank ..	16	0.02	0.10	0.05	5	0.20	0.35	0.27
(3) Ten Mile Denver Sluice	45	< 0.02	0.19	0.04	8	0.08	0.40	0.22

- (1) Approximately 3 km downstream of Ely
(2) Approximately 19 km downstream of Ely
(3) Approximately 24 km downstream of Ely

Note: The 3 samples taken at Roxton are not representative of the year as a whole: 2 were taken in July and 1 in September.

APPENDIX C
THAMES WATER AUTHORITY
METROPOLITAN WATER SERVICES

Concentration of Anionic Surfactants, Phosphates and Boron in the River Thames and River Lee

Analytical results—yearly averages in mg/l

	ANIONIC SURFACTANT (as Manoxol OT)					PHOSPHATES (as P)					BORON (as B)				
	1973	1974	1975	1976	1977	1973	1974	1975	1976	1977	1973	1974	1975	1976	1977
River Thames at Datchet ..	0.04	0.06	0.06	0.06	0.02	1.11	0.78	0.82	1.14	0.65	0.34	0.20	0.14	0.30	0.24
River Thames at Walton ..	0.04	0.07	0.06	0.06	0.03	1.17	0.85	0.91	1.11	0.65	—	—	0.16	0.33	0.22
Filtered water ..	0.02	0.02	—	0.03	—	0.98	0.88	0.62	1.11	0.62	—	—	—	—	—
River Thames treated water into supply (Ashford Common) —from Laleham and/or Datchet	0.03	0.03	0.02	0.04	0.02	0.98	0.88	0.68	1.04	0.69	0.32	0.24	0.15	0.26	0.24
River Lee at Chingford Mill ..	0.05	0.08	0.07	0.10	0.07	2.45	1.76	1.30	2.28	1.34	0.65	0.47	0.31	0.57	0.38
Coppermills Filtered water ..	0.04	0.03	0.03	0.04	0.03	1.41	0.98	1.11	1.60	0.98	0.36	0.29	0.24	0.37	0.28
River Lee at New Gauge (Ware) ..	0.03	0.06	0.05	0.08	0.07	0.98	0.69	0.75	1.14	0.88	0.36	0.28	0.21	0.34	0.32
New River filtered water into supply (Stoke Newington) ..	0.02	0.02	0.02	0.03	0.02	0.75	0.52	0.49	0.78	0.55	—	—	—	—	—

APPENDIX C
THAMES WATER AUTHORITY
METROPOLITAN WATER SERVICES

Nonionic Surfactant (as Lissapol NX in mg/l)

	RIVER THAMES AT DATCHET/WALTON					RIVER LEE AT CHINGFORD MILL				
	1973	1974	1975	1976	1977	1973	1974	1975	1976	1977
Average	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
Maximum	0.05	0.02	0.02	0.02	0.02	0.04	0.03	0.02	0.04	0.04
Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Note: Sampling point changed from Laleham to Walton in 1973 and to Datchet in 1975.

APPENDIX C

THAMES WATER AUTHORITY, METROPOLITAN WATER SERVICES

Concentration of Surfactant, Phosphate and Boron in the Thames and Lee

Analytical results—1977, Monthly averages in mg/l

	RIVER THAMES AT DATCHET/LALEHAM/WRAYSBURY			ASHFORD COMMON TREATED WATER			RIVER LEE AT CHINGFORD			COPPERMILLS TREATED WATER		
	Anionic Surfactant (as Manoxol OT)	Phosphate (as P)	Boron (as B)	Anionic Surfactant (as Manoxol OT)	Phosphate (as P)	Boron (as B)	Anionic Surfactant (as Manoxol OT)	Phosphate (as P)	Boron (as B)	Anionic Surfactant (as Manoxol OT)	Phosphate (as P)	Boron (as B)
January	0.02	0.39	0.13	0.03	0.78	0.23	0.06	0.98	0.23	0.03	1.08	0.26
February	0.02	0.16	0.10	0.02	0.62	0.23	0.05	0.82	0.28	0.04	0.69	0.25
March	0.02	0.39	0.18	0.02	0.62	0.15	0.05	0.69	0.23	0.01	0.33	0.16
April	0.04	0.42	0.23	0.02	0.42	0.15	0.05	1.11	0.28	0.02	0.59	0.20
May	0.02	0.55	0.24	0.00	0.49	0.18	0.09	1.11	0.33	0.02	0.78	0.26
June	0.00	0.59	0.21	0.01	0.46	0.21	0.07	1.31	0.48	0.02	0.78	0.36
July	0.02	0.62	0.24	—	0.52	0.26	0.09	1.26	0.58	0.04	0.95	0.35
August	0.03	0.75	0.33	0.01	0.55	0.30	0.07	1.50	0.33	0.02	0.98	0.35
September	0.03	0.88	0.37	0.01	0.85	0.30	0.07	1.70	0.40	0.04	1.04	0.28
October	0.02	1.21	0.37	0.01	0.82	0.33	0.08	1.79	0.57	0.04	1.93	0.47
November	0.04	0.91	0.24	0.02	0.98	0.27	0.09	1.93	0.45	0.04	1.34	0.38
December	0.04	0.69	0.20	0.02	1.08	0.31	0.07	1.60	0.42	0.04	1.17	0.41

APPENDIX D

DATA ON PRODUCTION FOR UK CONSUMPTION

(Thousand Tonnes)

	1973	1974	1975	1976	1977
Toilet Products—Toilet Soap	72.0	75.2	75.0	92.6	83.0
—Shaving Products and Shampoos (based on soap)	7.7	9.2	8.3	9.2	11.5
Household and Industrial Soaps	63.1	58.5	55.2	53.8	55.1
Total 'Soap' Products	142.8	142.9	138.5	155.6	149.6
'Detergent' Products					
(a) Washing Powders (Fabrics)*	372.2	383.9	365.0	352.4	362.5
(b) Washing Powders (Machine Dishwash)	4.0	4.1	5.4	5.5	4.0
(c) Surface Cleaning Powders	13.5	13.5	12.0	11.0	9.2
(d) Synthetic Liquid Products—Fabric Washing	4.0	3.5	3.5	2.3	2.1
—Dishwashing	130.0	133.0	137.0	137.0	154.1
—Fabric Softener	24.0	35.0	41.0	47.0	52.9
(e) Scourers	67.3	59.3	55.4	58.9	54.4
Total 'Detergent' Products	615.0	632.3	619.3	614.1	639.2

*Includes Soap Powders.

The above data were provided by the Soap and Detergent Industry Association. These figures cover the UK production of soap and detergent products for UK consumption.

The following quantities of surfactants are estimated by the industry to have been placed on the United Kingdom domestic product market in 1977:

Anionic 68,500 tonnes

Nonionic 16,000 tonnes

Cationic 3,300 tonnes

The Group for Organic Surfactant Intermediate Products (GOSIP), a Sector Group of the Chemical Industries Association, estimate the consumption of synthetic surface active agents in the United Kingdom for 1977 to be as follows:

Anionic surfactants: 105,000 tonnes

Nonionic surfactants: 44,000 tonnes

Cationic surfactants: 8,500 tonnes

(expressed as 100% active material).

The differences between the tonnages quoted above and those provided by the Soap and Detergent Industry Association represents the use in toiletries, the industrial usage of surfactants and the exports of finished products which are not included in the industry data. The majority of industrial uses of surfactants would lead to their discharge via trade effluent to sewage works. Some uses however, eg in paints, may not involve any appreciable environmental impact.

PERPUSTAKAAN
JABATAN ALAM SEKITAR

HER MAJESTY'S STATIONERY OFFICE

Government Bookshops

49 High Holborn, London WC1V 6HB
13a Castle Street, Edinburgh EH2 3AR
41 The Hayes, Cardiff CF1 1JW
Brazennose Street, Manchester M60 8AS
Southey House, Wine Street, Bristol BS1 2BQ
258 Broad Street, Birmingham B1 2HE
80 Chichester Street, Belfast BT1 4JY

*Government Publications are also available
through booksellers*

ISBN 0 11 751134 X

NINETEENTH PROGRESS REPORT OF THE STANDING TECHNICAL
COMMITTEE ON SYNTHETIC DETERGENTS

HMSO

Author has tracked acid rain

PAUL G. HAYES first wrote about acid rain 12 years ago, when, as environmental reporter for The Milwaukee Journal, he covered the United Nations Conference on the Human Environment in Stockholm, Sweden.

That conference brought together scientists and policy-makers from all over the world. They were responding to a public outcry against threats to natural values by industrial neglect, unrestrained development, population growth and new chemical compounds.

At that conference, Swedish researchers presented evidence that the life in some lakes in Sweden had been killed by increased acidity of the water. Forest damage also was noted. The Swedes blamed sulfuric acid that they believed was coming from industrial centers in Britain and Germany.

Twelve years later, the issue still is very much with us. Canada, like Sweden, believes that its lakes and forests are being harmed and it wants joint action with the US in controlling atmospheric acids.

The issue is technically complex and geographically widespread.



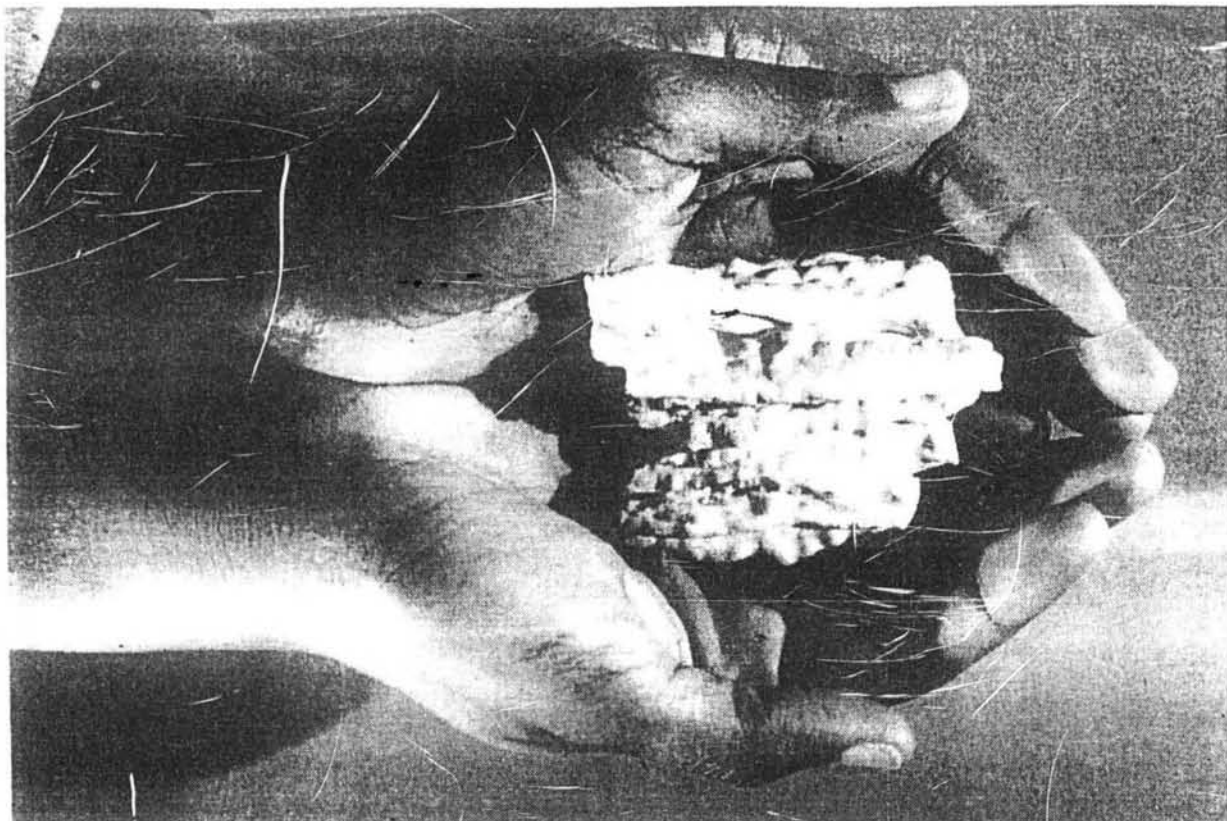
Paul Hayes

Much of the story has been told in bits and pieces. To put the subject into context, Hayes followed sulfur through commerce and the environment. He visited a coal mine in Kentucky, a power plant in Oak Creek and a maple forest in Ontario.

He sought to place sulfur, the main culprit in the acid-rain problem, into perspective as this element moves from south to north, sometimes as a valuable chemical, sometimes as a damaging pollutant.

Hayes, 50, of Cedarburg, joined The Journal Staff in 1962 and has been environmental, energy and, now, science reporter.

The Milwaukee Journal



MAIN ACTOR — This is sulfur, a valuable chemical in industry and the main actor in the acid rain controversy. Harmless in pure form,

when burned it forms sulfur dioxide gas. In sunlight, the gas becomes sulfuric acid. Result: Rain in the East is diluted acid.

—Journal Photo by Allen C. Fredrickson

THE ACID TRAIL I

Riding the ill winds of sulfur

By Paul G. Hayes

Journal Science Reporter

MADISONVILLE, KY. — About 450 miles south of Oak Creek, Wis., in the Colonial coal mine west of here, 143 union miners work in shifts around the clock digging out the seam of coal known as Kentucky No. 9.

And 500 miles east and slightly north of Oak Creek, the people of the Muskoka district of Canada worry about their lakes and trees.

The people of Oak Creek and all of southern Wisconsin depend upon the durable, old Oak Creek power plant of Wisconsin Electric Power Co. for much of their electricity.

Kentucky miners, Milwaukee electricity users and Canadian resort owners all are entangled in a complex chemical web involving a pale yellow element: sulfur. In the forms we will emphasize, sulfur becomes invisible but potent.

Commercial sulfur moves by pipeline, barge, rail and truck. Polluting sulfur moves by wind, rainfall and water current. As it does, it affects everything it touches.

Touches everyone

Directly, it touches human lives, including yours. It implicates jobs and companies. It affects the quality of our life, and it eats into your bill or purse.

This story about acid rain begins in western Kentucky, where two huge Bucyrus-Erie draglines, manufactured in South Milwaukee, bite into the earth of the Colonial mine.

Each dragline bucket, lined with

six steel teeth each as big as a man, chews into 80 feet of soil and rock that lie over the seam of coal.

With each bite, 75 cubic yards of earth and stone are removed. Envision a barrier 3 feet high, 3 feet wide and 225 feet long. That's the amount of material in each monstrous bucketful as it swings overhead, drooling earth and stones beneath it.

This eating away at the earth goes on 24 hours a day, seven days a week. Although the power plant of each dragline is the size of a 10-story building, it takes only three men to keep the draglines working.

They are among the 143 United Mine Workers union members working at Colonial mine. Colonial mine is one of several that maintain Madisonville's reputation as a coal-mining town. People here want to be coal miners, as their grandfathers and fathers were.

Bulldozers clean the top of the exposed coal seam by pushing loose rock and soil to the side. The coal bed looks like a black pavement before it is lifted out of the pits by shovels and dumped into waiting trucks.

Make way

Signs throughout the mine proclaim that coal-laden trucks have the right of way. So urgent is the efficient and unending flow of coal to mining profits, mining unions and commerce that everything and everybody make way for the giant trucks.

THE TRUCKS CLIMB deliberately out of the pits and rush their load to a bridge with a grid for a surface. The bottom of the

coal truck opens and coal falls through the grid. Conveyors move the coal into the washing house, where it is crushed to uniform size and washed to remove pyrite and other noncombustibles.

Twice a week, trains from Wisconsin arrive at the mine and pull under the loader. It takes about four hours to load one train.

The long trains leave the Colonial mine and two other mines in southern Illinois and western Kentucky burdened with coal. They move north, passing prairie towns in eastern Illinois: Effingham, Mattoon, Champaign, Kankakee.

In Chicago's vast railyards, they shift from Illinois Central Gulf's tracks to the Chicago and North Western Railway for the final 85 miles.

Six times each week, a train slides into Wisconsin Electric Power Co.'s Oak Creek Power Station. Each train has 110 black cars. Each car carries 200,000 pounds of black coal. Each lump of coal contains an average of 2.8% of sulfur.

At the plant, the North Western locomotive is uncoupled and replaced by Wisconsin Electric's on-site locomotive.

Automatic operation

This locomotive runs without an engineer. It is controlled remotely by radio by Joseph Williams, fuel equipment operator, from his control room overlooking the car dumper. By radio signal, he moves the train forward one car at a time.

Each in its turn, the cars are positioned onto a section of track directly in front of Williams. He hits a lever

and steel clamps grip the car like monstrous steel jaws.

Each steel coal car weighs 60,000 pounds. Remember, the coal each car contains weighs 200,000 pounds. Thus, the jaws grip 260,000 pounds.

The rotary car dumper flips its 260,000 pound load upside down as easily as you would upend a pan of water.

Coal spills into a hopper. No, it doesn't; it crashes into a hopper. Each car purges itself in a minute and a half. A train of 110 cars is emptied in about three hours.

Automatic vibrators shake the coal from the hopper onto conveyor belts. A trainload, 110,000 tons of coal, becomes part of an uninterrupted river of coal.

Coal courses along conveyor belts inside slanting tubes that run from the pit to the boilers along the top of the plant. The conveyors move 2,700 tons an hour along a belt that moves 700 feet a minute.

The conveyor room is heavy with a sweet, damp smell that might be unburned sulfur compounds.

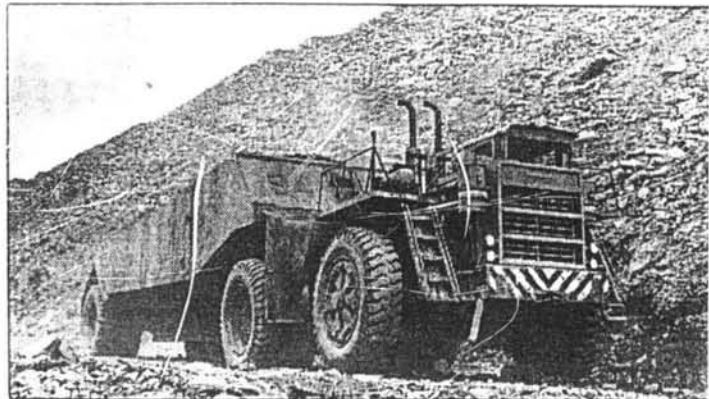
Blown into boilers

A black, gritty Niagara Falls of coal falls off conveyor belts into crushers that pulverize it into talcum-powder consistency. Now the fine dust of coal is blown forcefully into eight boilers of varying ages and sizes, the first built almost 40 years ago, the last in the 1960s.

Together the boilers have a capacity to generate 1,670,000 kilowatts of electricity, making Oak Creek by far the largest electricity-generating complex in all Wisconsin. The electricity provides light, comfort and



—Photo by Bobby Roe



—Journal Photo by Paul H.

The acid trail begins in the coal fields (left) of Kentucky, where sulfur-bearing coal is mined and hauled by huge trucks (above) to trains that transport coal to the Oak Creek Power Station (right). The coal is burned at the power station and the sulfur combines with oxygen to form sulfur-dioxide gas. Atmospheric processes convert the gas to sulfuric acid.



commerce to southeastern Wisconsin.

There are 19 other power plants in Wisconsin that burn coal. These and four nuclear reactors, 89 small power dams, and 48 intergal-combustion generators in Wisconsin can generate 9,620,326 kilowatts of electricity at any given instant.

Fully 17% of this statewide capacity is at Oak Creek, the old workhorse of Wisconsin's power plants.

Open the hatch on an iron peep-hole on just one of the eight boilers and the inner glow seems as bright as the sun. The temperature inside is 2,600 degrees Fahrenheit, almost hot enough to melt iron.

It is, indeed, sunlight that was captured by tropical forests 300 million years ago, during an era of great biological productivity, stored under Kentucky as coal and set free eons later at Oak Creek.

Four stacks, each serving two boilers, range in height from 350 feet for the two oldest to 557 feet for the newest. They don't appear to be that tall from a distance because the power plant is built at the foot of the Lake Michigan bluff.

Each boiler is equipped with an electrostatic precipitator that catches the unburnable ash, mostly oxides of aluminum, silicon and iron. About 265,000 cubic yards of fly ash were removed and disposed of on Wisconsin Electric's site last year.

Think of a barrier 3 feet high, 3 feet wide and 150 miles long, the distance from Milwaukee to Stevens Point. That's the volume of fly ash

that was disposed of in one year from the Oak Creek boilers.

Converted to gas

But only 2% of the sulfur that was in the coal remained with the ash. The rest was converted to sulfur-dioxide gas. Superheated, it rushed up the four stacks at almost 100 mph and entered the atmosphere as an invisible gas.

It is present in almost unimaginable volume: 143,000 tons of sulfur dioxide from Oak Creek alone in 1983. Half the weight is oxygen, half is sulfur. More than 70,000 tons of sulfur, or seven fully loaded traincars on one of Wisconsin Electric's trains.

In a sulfur-dioxide-rich atmosphere, your eyes sting, your nose burns and your lungs heave for lack of air. That's the reason the stacks at Oak Creek are so tall. It was recognized years ago that it wouldn't do to release all that sulfur dioxide close to the ground.

Released 350 to 557 feet high into the atmosphere, the fate of the sulfur dioxide is determined by wind, humidity, sunlight, other air pollutants, dust and temperature. It is a chaotic system, impossible to predict.

One thing is certain: The sulfur will come down again. Whether it comes down within three miles or 500 miles will be determined by atmospheric conditions.

In the presence of ultraviolet light, which the sun provides, or other catalysts, including metals, sulfur dioxide can take on another atom of oxygen to become sulfur trioxide.

NOW ALL THAT is needed for one molecule of sulfur trioxide to become a molecule of sulfuric acid is a single molecule of water.

Now let us watch Daniel Haworth, professor of chemistry at Marquette University, as he drops sulfuric acid of high strength onto organic molecules, those of table sugar and paper, in his MU laboratory.

It wants water

The acid, he said, is dehydrating. That is, acid has a great thirst. It wants water. Organic molecules are composed mostly of hydrogen, oxygen and carbon. Hydrogen and oxygen form water.

"Sulfuric acid has such a propensity for water that it turns the hydrogen and oxygen in any compound into water and leaves the carbon," said Haworth. "A tiny little drop on your skin would feel like a bee sting."

Thus, the thirsty acid grabs the hydrogen and the oxygen and rips it out of the organic molecules.

Within minutes, the sugar boiled up into a crisp, black ash that rose above its beaker. The white paper towel likewise turned black and fragile.

That's what nearly pure sulfuric acid does to organic molecules in laboratory beakers.

But mix sulfuric acid with a million parts of water in the atmosphere, said Richard C. Bratcher, manager of environmental planning and projects for Wisconsin Electric

Power Co., and one doesn't know its effects.

Now, focus again on Oak Creek and the 143,000 tons of sulfur dioxide entering the atmosphere each year from its stacks.

There are 19 other major utility-owned coal-burning power plants in Wisconsin. There are other major sulfur emitters in Wisconsin, including pulp mills and industry-owned power plants.

Together, they sent 671,000 tons of sulfur dioxide into the atmosphere in 1980 alone. Because half the weight of sulfur dioxide is sulfur, they sent 335,500 tons of pure sulfur into the air that year.

That caused Wisconsin to rank 16th among the top sulfur-dioxide-emitting states. Ohio led the 1980 list with 2,641,000 tons of sulfur dioxide; followed by Pennsylvania with 2,018,000; Indiana 2,004,000; and Illinois 1,468,000.

Kentucky, West Virginia, Ohio, Pennsylvania and Illinois also are the states with vast resources of high-sulfur coal. Because they also mostly are underlain with limestone, which has the effect of neutralizing acid, they may suffer less damage from acid.

These three facts — that these states mine high-sulfur coal, that they emit much of the sulfur dioxide in the nation, and that most of them are more protected by nature from the effects of acid — may explain why some of these states are political fortresses against legislation to control acid rain.

Sulfur plays the 'if' game

IT WAS EASY to follow a bit of sulfur from a coal mine in western Kentucky to Oak Creek where it was burned in Wisconsin Electric's Oak Creek power plant and sent up the stacks as sulfur dioxide.

But now the acid trail grows cold.

The sulfur dioxide flew out of the stacks at about 100 mph to join whatever other chemicals contaminate the atmosphere of industrialized Milwaukee. Among these are oxidizing agents, heavy metals, inert fly ash, dust, hydrocarbons.

Nitrous oxides are among them, too, not only from coal-burning power plants, but also from petroleum burned in industry and, mostly, motor vehicles. Nitrous oxides become acid in the atmosphere, too. It also harms. It is part of the acid-rain problem.

Some atmospheric acid is present naturally. Rainfall is not benign; it naturally is slightly acidic. Natural systems have evolved, of course, to cope with some acidity. This confounds the debate. It complicates the problem.

In these articles, however, we are trailing sulfur, the main element in acid rain.

Dictated by weather

Once out the stack, the weather near the power plant will dictate the fate of the sulfur. If the sulfur dioxide enters clouds or fog, sulfuric acid may form within minutes.

If it doesn't, the gases may stream downwind, at various altitudes, for hundreds of miles, growing more and more diluted. Sulfuric acid in air now

must be measured in parts per million.

Concentrating on one molecule among a million is like concentrating on a single inch in a road almost 16 miles long.

If the gas enters clear, dry air, it may remain for a time as sulfur dioxide. If it forms acid in the atmosphere, the presence of some kinds of dust may neutralize some of it.

If it moves south before it falls out, it may do less damage because of differences in the chemistry of the bedrock, than if it moves north. If the rain comes in a downpour, the acid may be more diluted than if the rain comes as a shower.

If it falls in urban areas, it may etch paint, corrode metals and eat into limestone or marble buildings or monuments. Depending upon the weather, it may stay aloft for only hours and fall to the ground within a few miles. Or it may stay aloft for weeks and cross international boundaries.

Can be neutralized

If it falls on ground, it might wash into the soil. If the soil is in an area underlain with limestone bedrock, the acid may be neutralized. Or the acid may liberate aluminum or mercury or other heavy metals from rock and allow these poisons to go to work.

If the metals are in waterways, they kill individual fish, or they may interrupt the reproductive cycles of life forms. It may be that acid is freeing mercury from bedrock that is concentrating in fish that makes eating fish from some Wisconsin waters unhealthy.

If sulfate falls in winter on a snow cover, it may not become dangerously acidic until the spring thaw. If the ground was frozen before the snow fell, almost all of the spring runoff may enter streams and lakes and cause what is known as the "spring shock," the season's worst assault of acid on the life of those lakes and streams.

Thus, it may be pointless to discuss "safe" averages of acidic rainfall. One event theoretically could do a year's worth of harm.

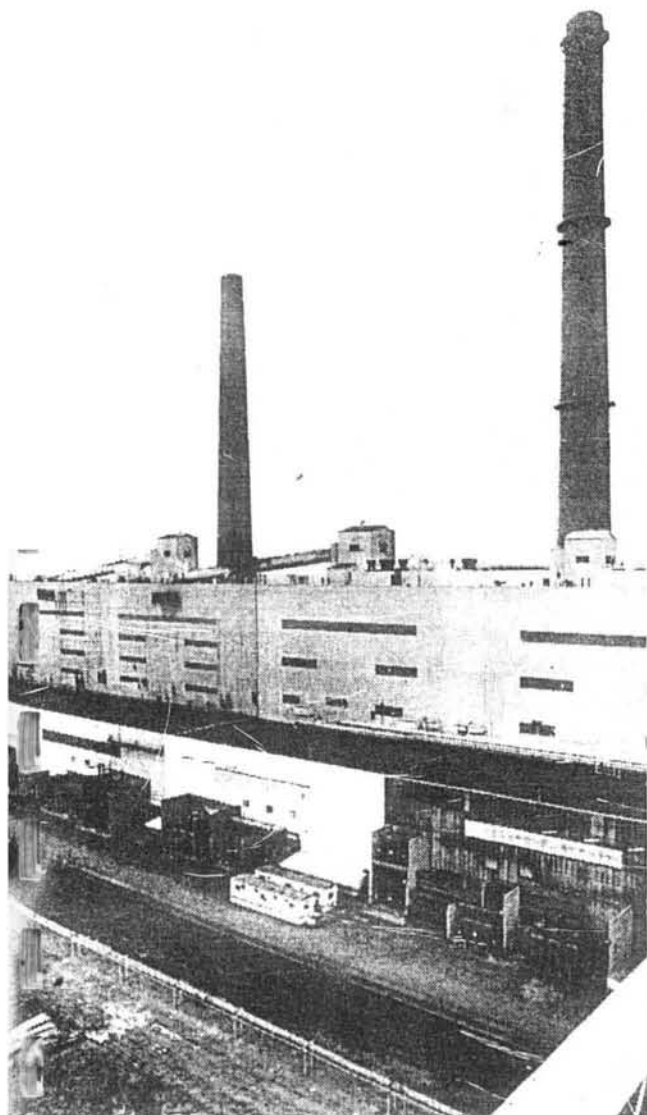
If the ground was not frozen before the snow fell, and the frost line was shallow, the acid may enter the soil.

If the watershed in which it fell was small, and the landforms are such that they funnel the runoff directly into a small lake, the runoff may increase the acidity of already acidic water.

IF ACID FALLS on trees already under stress by other environmental factors, or if they are diseased, the acid may be the final insult that causes the tree or a part of the tree to die, or to shed its leaves earlier than normal.

Species react differently. If acid falls on a pine tree, which has an affinity for acid, it may not cause any damage. If acid falls on a maple tree, it may attack and kill organic molecules in the leaf.

If it falls in spring, young leaves and buds may be more vulnerable than if it falls in late summer. If there is dust on the leaf, the acid may



—Journal Photo by Michael Sears

Sulfur: an essential, old friend

EVERY CHILD who owned a chemistry set knows what sulfur is and probably has inhaled a good stinging whiff of sulfur dioxide gas. Such sets usually include a pale yellow powder that burns easily, changing to a dark liquid and the acrid gas.

For the rest of you, sulfur is the main actor in the acid-rain controversy that has the people of two continents, Europe and North America, concerned about damage to forests and lakes.

Yet sulfur is an old friend to civilization. Ancient Egyptians used sulfur-containing gases to bleach cloth as early as 2000 B.C. The Romans used it medicinally.

In 1777, Antoine Lavoisier, a French chemist, identified sulfur as an element. It is No. 16 on the Periodic Table of the Elements. A solid at room temperature, it is yellow, brittle, odorless, tasteless and insoluble in water.

Seldom alone

Sulfur atoms do not like to be alone. Thus, each atom commonly joins with seven other sulfur atoms all linked in a circle to form a molecule of pure sulfur.

Of the more than 100 elements that compose Earth, sulfur is thought to be 15th in abundance, making up about one-fifteenth of the Earth's crust. It occurs as the pure element in some geological formations but far more abundantly as sulfide ores, some of which are found in northern Wisconsin.

Sulfur reacts directly with almost all other elements except gold, iodine, platinum and some gases. Thus, thou-

sands of chemical compounds contain sulfur. Most copper, zinc, nickel and lead ores are sulfides, and smelters of such ores are major emitters of sulfur dioxide.

Sulfur joins readily with iron to become ferrous sulfide, or pyrite, and this is a major contaminant in coal. Washing coal removes much pyrite, but other sulfur is not liberated from the coal until it is burned.

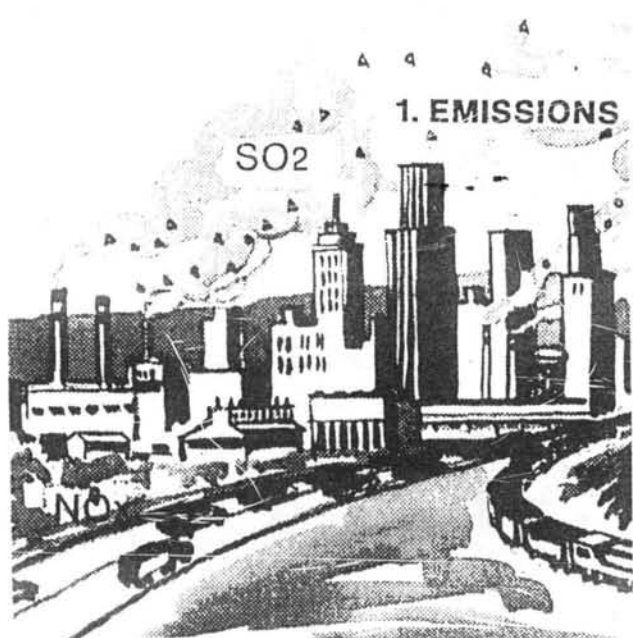
Your body contains sulfur, also, as an essential component of some proteins. These are present in skin, hair and nails more than elsewhere in the body. Although sulfur is essential to nutrition, there are no official minimum standards for human use. Why not? It is so abundant in food that human sulfur deficiencies are unheard of.

Like rotting eggs

Sulfur, odorless as an element, forms some of the stinkiest compounds known, particularly when it comes as hydrogen sulfide, the gas that forms in rotting eggs.

But sulfur is an essential contributor to our way of life. One of the four basic raw materials of the chemical industry — along with coal, limestone and salt — the industrial revolution would have unfolded far differently without it. Today, sulfur is essential in thousands of processes and is dominant in making fertilizers.

And as sulfur-dioxide gas and sulfuric acid in the atmosphere, it is one of the persistent environmental worries that arise from burning vast amounts of sulfur-containing coal and oil.



the issue substance. If anything, concern has deepened. Nothing has been found to suggest that the problem can be dismissed.

The National Academy of Sciences says there is no evidence that if you cut sulfur emissions you won't be cutting acid rain by the same percentage. The statement was a masterpiece of scientific caution.

What is most important, Bratcher said, is that there is no evidence that millions of dollars spent on sulfur control programs will have any detectable impact on the environment.

"More research is justified," Bratcher said. "To go beyond that, I wouldn't feel good about spending money on a lot of controls that aren't justified."

Research, not controls

Bratcher, a chemist, represents the consensus in Wisconsin; that is, research is justified but not controls. Furthermore, if controls are ordered, they should be applied nationally so as to keep Wisconsin economically competitive with other states.

But that consensus may be changing. Two state laws passed by the last Legislature deal with sulfur.

One imposes a cap of 500,000 tons of sulfur dioxide emissions a year on the five major electricity utilities. The other calls for a study of the costs and effects of various sulfur-dioxide controls.

In addition, the Wisconsin Department of Natural Resources has a new rule calling for reductions of sulfur dioxide to meet older federal laws aimed at controlling localized sulfur-dioxide air pollution to protect public health.

Utility managements suspect it really is aimed at acid rain. DNR officials deny it. The effect of it may be that Wisconsin's utilities will cut a higher percentage of its sulfur dioxide emission than New York will under its new law.

A few months ago, when a DNR staff member said publicly that Wisconsin was sufficiently at risk from acid rain for its Legislature to consider unilateral controls, without waiting for federal legislation, his bosses told him quietly to keep his opinions to himself.

Not many weeks later, Gov. Earl said much the same thing as the employe did.

ACID RAIN — Acid rain comes from burning fossil fuels, such as coal, gas and oil.

be neutralized before it can harm anything.

If there is a cloudburst over a lake that is rich in lime, of course, the acid will be neutralized. If the lake is deep and the acid strong, the acid may harm individual organisms of algae, plankton, fish or their eggs before it is neutralized and falls to the bottom as calcium sulfate.

This game of "ifs" has been going on for years. It became popular in 1972, when, during the United Nations Conference on the Human Environment in Stockholm, Sweden, the Swedish delegation distributed a little red and white booklet.

It was called "Air Pollution Across National Boundaries. The Impact on the Environment of Sulfur in Air and Precipitation." It said lakes and streams in southwester Sweden were being harmed by sulfuric acid that Swedish scientists thought was coming from industrial Britain and Germany.

Today the scientific pursuit that would either clear or blame sulfur dioxide for observed environmental damage grows larger and more expensive.

Millions of dollars are being spent and thousands of scientists are at work on hundreds of experiments to find what is happening after sulfur dioxide leaves power plants in the states east of the Mississippi.

Why is it so difficult to link sulfur dioxide from power plants with environmental damage? After all, there was no mistaking the destruction that high-strength sulfuric acid inflicted upon organic molecules in the Marquette University laboratory of Chemistry Prof. Daniel Haworth.

Global laboratory

But dilute that sulfuric acid by factors of a million and turn it loose in a soup of other chemicals that are reacting in a chemistry set the size of the globe, and the dramatic cause-and-effect seen in the laboratory dissolves.

Twelve years after the Stockholm conference, if you ask about acid rain in the United States, you still get conflicting views.

In New York, biologists found 200 lifeless lakes in the Adirondacks. They found an alarming dieback of

six species of deciduous trees at high altitudes. New York's Legislature didn't wait for the 10-year federal research program to be completed. It acted last July to cut sulfur emissions.

THE NEW LAW CALLS for a two-stage reduction in sulfur-dioxide emissions to be accomplished by utilities in any way they see fit. The amount to be cut depends upon a formula, but basically, it would be New York's share of a 10-million-ton reduction from the states east of the Mississippi River.

Thomas W. Faist, chief counsel for New York Sen. John R. Dunne (R-Garden City), who sponsored the bill, said the first stage was to be finished by 1988. The New York Department of Environmental Conservation will determine by 1991 whether the cut-back did any good.

If benefits can't be found in the natural environment, Faist said, "we're not going to shoot ourselves in the foot twice."

If, however, improvements are found, the second phase will begin.

The legislation, Faist said, drew support because:

New York already had suffered environmental damage.

About 30% of the state's problem was caused by sources of acid inside New York.

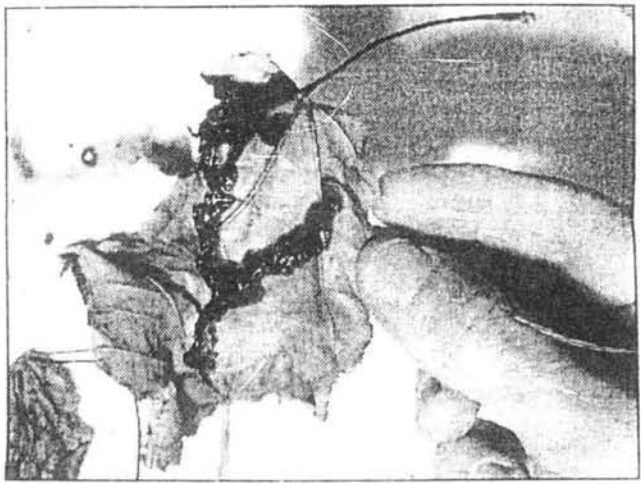
New York would have more clout in lobbying for national controls if it already had "bitten the bullet."

Studies in Wisconsin do not indicate an emergency here, said Richard Bratcher, manager of environmental planning and projects for the Wisconsin Electric Power Co., and a utility representative on the state's Joint Acid Deposition Technical Review Committee.

"It is true that Wisconsin has resources that are susceptible to acid deposition," he said. "It is also true that acid rain is falling in Wisconsin."

But it is not true that scientists have found significant harm in forests, lakes and streams or other assets, he said.

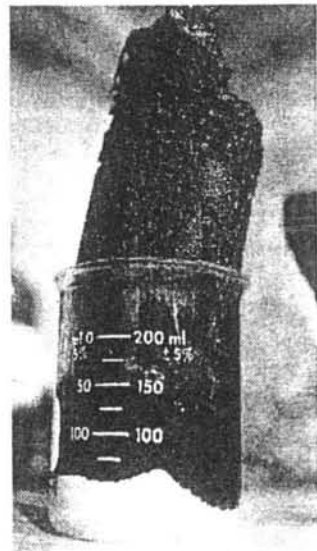
Nor is there evidence that the problem is a bugaboo. Research, both nationally and statewide, has given



IF ACID RAIN falls on a maple tree, it may destroy molecules in the leaf, but at a level hard to observe. There was no mistaking the destruction that high-strength sulfuric acid inflicted on a leaf in the Marquette University laboratory of chemistry Prof. Daniel Haworth.

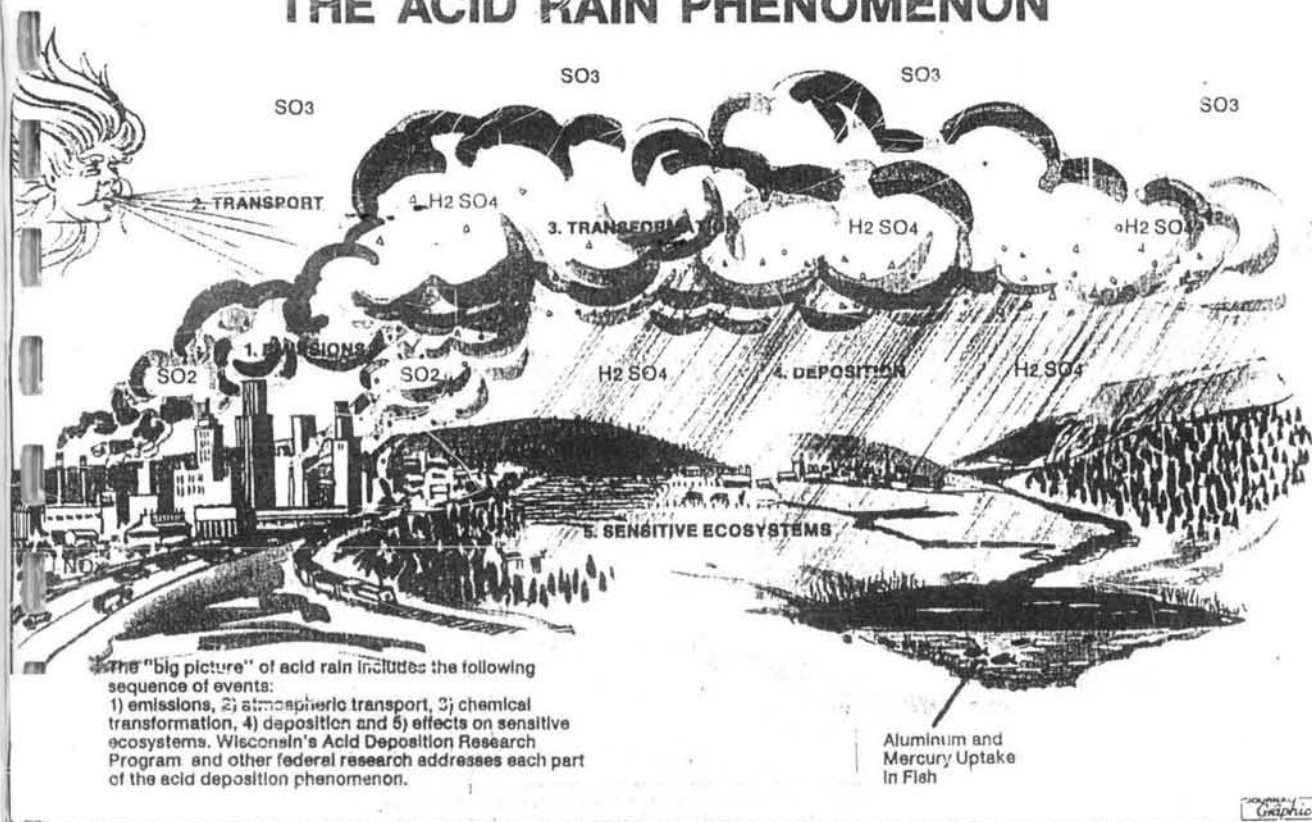


Daniel Haworth dropped a solution of sulfuric acid onto table sugar.



The acid took up the hydrogen and oxygen and left behind carbon.

THE ACID RAIN PHENOMENON



by Journal Artist Marlo D. Cain

Lake looks inviting; fish know better

LORENCE COUNTY, WIS. — When you learn its secret, Morgan Lake presents an unnerving message.

Blow nowhere around this alluring, clear-water jewel in the Nicolet National Forest is its secret publicly told, not in the public campground and beach on its south shore, nor at the boat-launching ramp on its west bank.

"The fishery is gone," said Tony Kinalid, wildlife and fish biologist for the Nicolet National Forest. "In the early '70s, there was a documented fishery there."

It may be that fishermen naively launch their boats there. If they have luck at all, they'll think it is very good luck. If they catch a fish, chances are it will be a lunker bluegill, pumpkinseed or largemouth bass.

But it is far more likely that they won't catch anything. The fish, it is believed, are not reproducing. There may be no fish left. The few, if any, that survive have little competition in their search for food and are growing larger — and older.

Morgan Lake shows all the classic signs of a lake gone acidic, said Thomas Sheffy, chairman of the Wisconsin Department of Natural Resources' Acid Deposition Task Force. It has high levels of sulfate and aluminum. But scientific proof that it was caused by industrial sources of acid is lacking.

At 48 acres and a depth of 12 feet, it's a small, shallow lake whose vulnerability to acid may be intensified by a small watershed that allows a great proportion of rainfall to run

directly into the water, rather than through the ground.

James Hodgson, professor of zoology at St. Norbert College, De Pere, said Morgan Lake had high acidity and no detectable fish reproduction.

Acidity and alkalinity are measured by scientists on a scale of 0 to 14, with 14 being the most alkaline and 0 being the most acidic.

On the so-called pH scale, 7 is considered neutral. It is a logarithmic scale in which pH 6 would be 10 times more acidic than pH 7 and pH 5 would be 10 times more acidic than pH 6 and 100 times more acidic than pH 7.

In 1971, Hodgson said, Morgan Lake was tested as having a pH of 6, not even as acidic as normal rainfall. In 1983, he said, he tested it as having a pH of 4.67.

"At pH 5.5," he said "fish begin to drop out of the system. Planktonic life does, too. That helps explain the extreme clarity of acidic lakes. What's left are a few alga forms and copepods, or microcrustaceans."

Wisconsin's 14,947 lakes, the state's glacial legacy, are the basis for a lifestyle and a tourist industry. The DNR says 3,500 of these lakes have a chemistry that makes them vulnerable to acid rain. That is, they have low alkalinity and therefore limited capacity to neutralize acid.

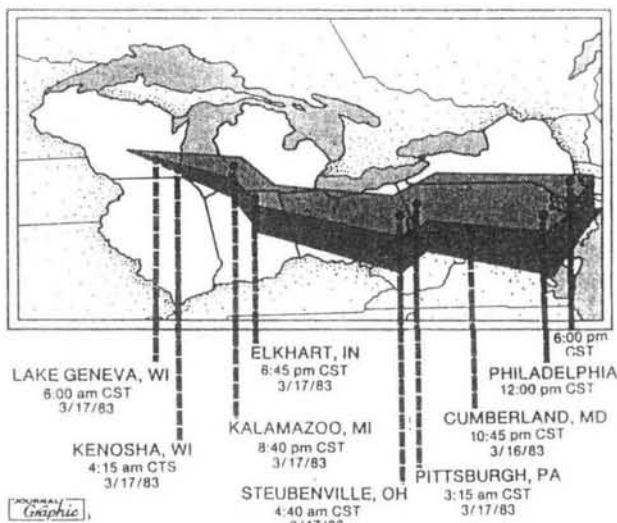
Fishless Morgan Lake may be Wisconsin's first human-caused victim of acid rain. But it was an accident.

The next victim, the northern half of Little Rock Lake in Vilas County, will be on purpose. Next July, scientists will begin to dump acid into the lake, gradually, so that acidic effects

on the lake's biological systems can be observed and recorded.

To understand what is happening, understand that "acid" is another word for "sour."

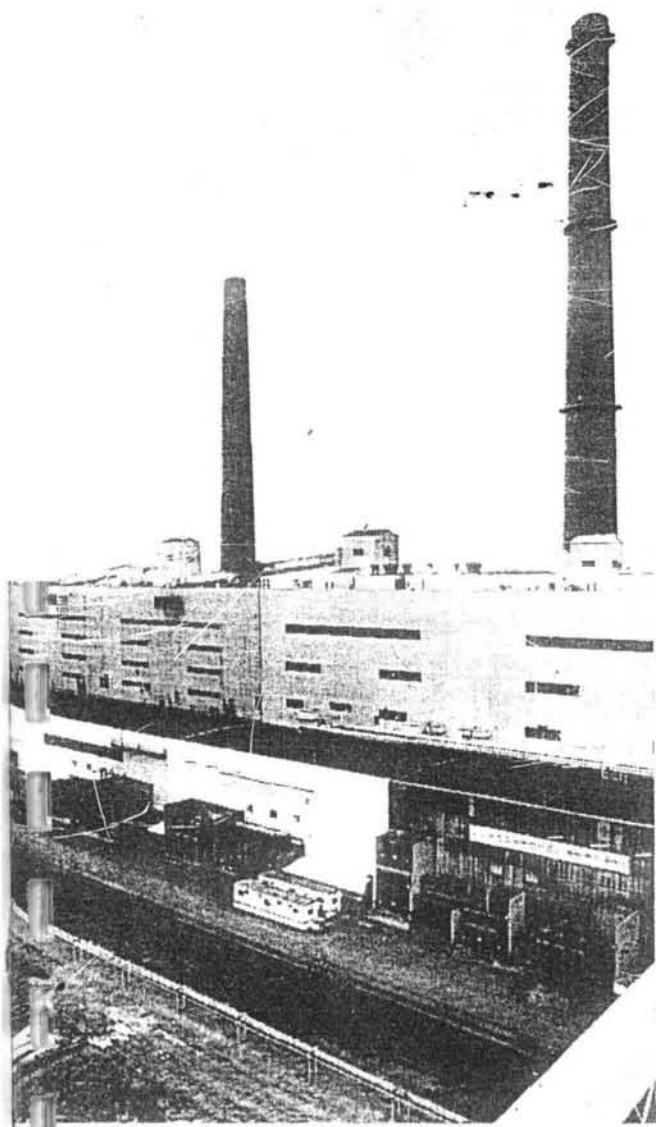
At present, the water of Little Rock Lake is as sour as white bread, or roughly a pH of 6. When all the acid has been applied, half of Little Rock Lake will be almost as sour as



Where does acid in Wisconsin lakes come from? This analysis of a storm over Lake Geneva on March 18, 1983, shows that the acid was brought in on an easterly wind from as far east as Philadelphia. Using weather records and a computer, scientists simulated the acid trail. Scientists concluded that 80% of the sulfuric acid that fell on Lake Geneva originated from outside Wisconsin; the rest from inside.

THE ACID TRAIL II

Sulfur plays the 'if' game



—Journal Photo by Michael Sears

IT WAS EASY to follow a bit of sulfur from a coal mine in western Kentucky to Oak Creek where it was burned in Wisconsin Electric's Oak Creek power plant and sent up the stacks as sulfur dioxide.

But now the acid trail grows cold.

The sulfur dioxide flew out of the stacks at about 100 mph to join whatever other chemicals contaminate the atmosphere of industrialized Milwaukee. Among these are oxidizing agents, heavy metals, inert fly ash, dust, hydrocarbons.

Nitrous oxides are among them, too, not only from coal-burning power plants, but also from petroleum burned in industry and, mostly, motor vehicles. Nitrous oxides become acid in the atmosphere, too. It also harms. It is part of the acid-rain problem.

Some atmospheric acid is present naturally. Raintail is not benign; it naturally is slightly acidic. Natural systems have evolved, of course, to cope with some acidity. This complicates the debate. It complicates the problem.

In these articles, however, we are trailing sulfur, the main element in acid rain.

Dictated by weather

Once out the stack, the weather near the power plant will dictate the fate of the sulfur. If the sulfur dioxide enters clouds or fog, sulfuric acid may form within minutes.

If it doesn't, the gases may stream downwind, at various altitudes, for hundreds of miles, growing more and more diluted. Sulfuric acid in air now

must be measured in parts per million.

Concentrating on one molecule among a million is like concentrating on a single inch in a road almost 16 miles long.

If the gas enters clear, dry air, it may remain for a time as sulfur dioxide. If it forms acid in the atmosphere, the presence of some kinds of dust may neutralize some of it.

If it moves south before it falls out, it may do less damage because of differences in the chemistry of the bedrock, than if it moves north. If the rain comes in a downpour, the acid may be more diluted than if the rain comes as a shower.

If it falls in urban areas, it may etch paint, corrode metals and eat into limestone or marble buildings or monuments. Depending upon the weather, it may stay aloft for only hours and fall to the ground within a few miles. Or it may stay aloft for weeks and cross international boundaries.

Can be neutralized

If it falls on ground, it might wash into the soil. If the soil is in an area underlain with limestone bedrock, the acid may be neutralized. Or the acid may liberate aluminum or mercury or other heavy metals from rock and allow these poisons to go to work.

If the metals are in waterways, they kill individual fish, or they may interrupt the reproductive cycles of life forms. It may be that acid is freeing mercury from bedrock that is concentrating in fish that makes eating fish from some Wisconsin waters unhealthful.

If sulfate falls in winter on a snow cover, it may not become dangerously acidic until the spring thaw. If the ground was frozen before the snow fell, almost all of the spring runoff may enter streams and lakes and cause what is known as the "spring shock," the season's worst assault of acid on the life of those lakes and streams.

Thus, it may be pointless to discuss "safe" averages of acidic rainfall. One event theoretically could do a year's worth of harm.

If the ground was not frozen before the snow fell, and the frost line was shallow, the acid may enter the soil.

If the watershed in which it fell was small, and the landforms are such that they funnel the runoff directly into a small lake, the runoff may increase the acidity of already acidic water.

IF ACID FALLS on trees already under stress by other environmental factors, or if they are diseased, the acid may be the final insult that causes the tree or a part of the tree to die, or to shed its leaves earlier than normal.

Species react differently. If acid falls on a pine tree, which has an affinity for acid, it may not cause any damage. If acid falls on a maple tree, it may attack and kill organic molecules in the leaf.

If it falls in spring, young leaves and buds may be more vulnerable than if it falls in late summer. If there is dust on the leaf, the acid may

Sulfur: an essential, old friend

EVERY CHILD who owned a chemistry set knows what sulfur is and probably has inhaled a good stinging whiff of sulfur dioxide gas. Such sets usually include a pale yellow powder that burns easily, changing to a dark liquid and the acrid gas.

For the rest of you, sulfur is the main actor in the acid-rain controversy that has the people of two continents, Europe and North America, concerned about damage to forests and lakes.

Yet sulfur is an old friend to civilization. Ancient Egyptians used sulfur-containing gases to bleach cloth as early as 2000 B.C. The Romans used it medicinally.

In 1777, Antoine Lavoisier, a French chemist, identified sulfur as an element. It is No. 16 on the Periodic Table of the Elements. A solid at room temperature, it is yellow, brittle, odorless, tasteless and insoluble in water.

Seldom alone

Sulfur atoms do not like to be alone. Thus, each atom commonly joins with seven other sulfur atoms all linked in a circle to form a molecule of pure sulfur.

Of the more than 100 elements that compose Earth, sulfur is thought to be 15th in abundance, making up about one-fifteenth of the Earth's crust. It occurs as the pure element in some geological formations but far more abundantly as sulfide ores, some of which are found in northern Wisconsin.

Sulfur reacts directly with almost all other elements except gold, iodine, platinum and some gases. Thus, thou-

sands of chemical compounds contain sulfur. Most copper, zinc, nickel and lead ores are sulfides, and smelters of such ores are major emitters of sulfur dioxide.

Sulfur joins readily with iron to become ferrous sulfide, or pyrite, and this is a major contaminant in coal. Washing coal removes much pyrite, but other sulfur is not liberated from the coal until it is burned.

Your body contains sulfur, also, as an essential component of some proteins. These are present in skin, hair and nails more than elsewhere in the body. Although sulfur is essential to nutrition, there are no official minimum standards for human use. Why not? It is so abundant in food that human sulfur deficiencies are unheard of.

Like rotting eggs

Sulfur, odorless as an element, forms some of the stinkiest compounds known, particularly when it comes as hydrogen sulfide, the gas that forms in rotting eggs.

But sulfur is an essential contributor to our way of life. One of the four basic raw materials of the chemical industry — along with coal, limestone and salt — the industrial revolution would have unfolded far differently without it. Today, sulfur is essential in thousands of processes and is dominant in making fertilizers.

And as sulfur-dioxide gas and sulfuric acid in the atmosphere, it is one of the persistent environmental worries that arise from burning vast amounts of sulfur-containing coal and oil.

grapes or tomatoes, with a pH of 4.5, more than sufficient to kill most of the life in the lake.

The south lobe of Little Rock Lake has been separated by a sea curtain from the north lobe. Changes in the north lobe will be measured against the south lobe.

At the end of the experiment, the north lobe will be restored, naturally, if possible, or by introducing acid-neutralizing lime into the lake. Life forms from the south lobe should restock the north lobe.

Meantime, acid rain is falling into all Wisconsin lakes. The DNR has observed rains as acidic as 3.35 pH (pickles, grapefruit or cider) at Lake Geneva Aug. 8, 1982, to 7.16 (hard water) at Spooner Oct. 7, 1980.

Where was it coming from? The DNR contracted with a Boston consulting firm, Charles T. Main Inc., to feed weather and acid data into a computer to see if the model could back-trace the path of the acids.

To test the method, Main studied six different storms that rained acidity upon three lakes: Legend Lake, east of Keshena in Menominee County; Lake Geneva, in Walworth County; and Round Lake in Douglas County, the far northwestern county of Wisconsin.

Preliminary findings indicated that the chemicals that caused the atmospheric acids could be coming from sources both inside and outside Wisconsin, some from as far away as

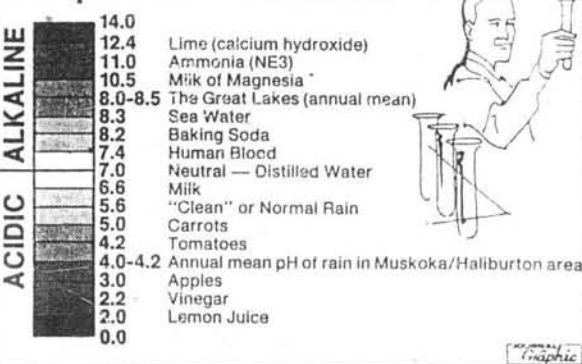
Louisiana, Mississippi, the Ohio River Valley, New Jersey, Delaware and Pennsylvania.

Or they could come from as close as Milwaukee or Green Bay.

Acid rain could arrive at the lakes from every direction, including the northeast, from Canada.

In short, Wisconsin was a contributor and a receiver of acid rain.

The pH Acidic Parameter



Your taste buds can help you understand what is happening to many lakes. To your taste buds, "acid" means "sour." To scientists, acidity is measured on the pH scale in which pH 6 is 10 times more acidic than pH 7 and pH 5 is 10 times more acidic than pH 6. This chart shows the pH values of familiar items. Morgan Lake in the Nicolet National Forest, a typical example of a lake gone acidic, went from a pH value of 6, less acidic than normal rain, in 1971 to 4.67, more sour than carrots, in 1983.

THE ACID TRAIL III

Jobs, trees and acid rain

By Paul G. Hayes

Journal Science Reporter

MUSKOKA, ONTARIO — The lives of people along the acid trail are intertwined. What happens to those in one place may affect those in others. Some believe that their lives already have been changed by acid rain or its politics.

Some Canadians and some Kentuckians are convinced of it.

Marguerite Stimpson, 73, is a lifelong resident of the Muskoka district, a resort area in Ontario east of Lake Huron's Georgian Bay that seems biologically identical to northern Wisconsin.

"I was born here," she said. "I can remember flowers and foliage many years ago that simply died out. The trees around my place show damage."

"There is a sugar maple at the back of my house that shows damage at the top. The tree is partly protected by my roof; if it rains, the leaves on the outside are damaged, but the leaves under the roof are not damaged."

"In my lily pond, I have frogs and toads and salamanders. The eggs didn't hatch three years ago. Two years ago, I brought in three big limestone rocks and surrounded [them] with crushed limestone, and for two years, I got the hatch."

Stimpson is not a scientist, but she harbors no doubt whatsoever that acid from the sky is a threat that already has caused great harm.

East of Lake Muskoka, in Haliburton County, Ross Boothby, 46, wandered through his 300-acre maple grove, where three generations of Boothbys have tapped the trees for maple syrup.

"Grandfather Egbert Boothby from England pioneered this area before the turn of the century," Boothby said. "Maple syrup was his sweet. Grandfather died the year I was born."

Ross Boothby runs a resort near here. Each spring, before the resort business begins to command all his time, he produces 200 to 300 gallons of maple syrup from 1,500 taps.

"I almost know every tree personally, you know, and I know that that tree hasn't been improving at all."

He pointed to the crown of a tall maple near the path. The crown was leafless.

"I noticed the dieback in 1978," he said. "I guess there has been a 5% to 10% loss. Right now, it seems to have stabilized. You can see some trees putting out new growth below dead wood."

"Father kept records in the 1940s," he said. "I've increased the number of taps, but the per-tree production has not increased. When you drill the tree, the tap hole itself is not healing well."

Boothby is not a scientist, either, but he suspects acid rain.

Canadian scientists do, too. They were on Boothby's property that September day taking wood samples and other information to dissect in their search for the cause of the dieback. The results are not in.

Black Forest

Forest damage, noticed in the Black Forest of Germany as well as high in the Adirondack Mountains of New York and in the sugar groves of Ontario, is the newest worry involving acid rain.

Atmospheric acid is a suspect, but not necessarily the criminal. If the culprit is acid, it may be nitrous acid, most of which is caused by automotive exhausts, rather than sulfuric acid, most of which can be traced to coal-burning power plants.

Thomas G. Brydges, coordinator of acid deposition research for Ontario's Ministry of the Environment, said research so far suggested that acid might be the agent that pushed an already stressed tree over the edge.

ACID MAY FALL onto the upper leaves and thereby use up calcium in the crowns of the trees. The acid rain then might fall from the upper leaves to enter the shallow soils, where it reacts with calcium, tying it up. As a result, calcium, an essential element in plant life, is no longer available to the trees and other plants.

"The branches send a message down to the roots, 'Send up more calcium,' and the roots say, 'We just

ran out.' And then you get damage to root hairs because they don't have calcium enough to neutralize the acid," Brydges said.

The acid also can react with rocks to make heavy metals that are toxic to plants.

Despite the maple dieback, Canada has no studies showing widespread forest productivity losses in recent years. For that matter, no such studies exist for national forests in Wis-

consin, according to the US Forest Service office in Milwaukee.

The Muskoka-Haliburton economy is based upon tourism. Its tourism, in turn, is based upon fish-filled lakes and flourishing forests. Shallow soils and bedrock with limited capacity to neutralize acid leave the area vulnerable to any acid deposition. It is understatement to say that residents here are worried about acid rain.

They are mobilized, as is most of



Ross Boothby suspects rain has damaged his trees



—Photos by John Black

Marguerite Stimpson put limestone rocks in her lily pond to counteract the effects of the acid rain

Canada. In fact, a recent Gallup Poll indicated that 69% of Canadians would be willing to donate a full day's work each year for the specific purpose of cleaning up acid rain in Canada.

Canada is a source of acid rain, too. In fact, for a time it was the world's bad example of sulfur emissions.

Madbury, Ontario, northwest of Muskoka, still houses the largest source of sulfur-dioxide emissions in North America, the International Nickel Co.'s (INCO) nickel smelter.

Decades of smelting sulfide ores — in the early days it was done in the open at ground level — had left the landscape so barren as late as the 1950s that the Apollo astronauts tried there for moon walks.

With the building of tall stacks and later with orders from the provincial government to cut sulfur emissions, the INCO and nearby Falconbridge smelter reduced sulfur emissions by about 80% from their peak years.

In sulfur cutbacks, the Canadians are ahead of the US. In controlling automobile emissions, a main source of nitrous oxides, they lag. Hearings were held recently in Ottawa that could lead to catalytic converters being placed on all new Canadian cars.

Since 1979, Canadian political sentiment has coalesced into a united front that has swept through local, provincial and federal governments, private industry and southward into the United States.

In the United States, a similar force encounters much sympathy in New England and some in northern Wisconsin and Minnesota areas, which, like eastern Canada, are chemically vulnerable to acids.

Farther south, in the states where high-sulfur coal is mined, it meets skepticism and hostility.

To observe strong political feelings on the other side of the acid-rain issue, visit western Kentucky, where high-sulfur coal is mined. This is the coal that is sent by the trainload to Wisconsin, where it is burned in the Oak Creek power plant of Wisconsin Electric Power Co.

SAID ROSCOE E. MILLER, secretary-treasurer of District 23 of the United Mine Workers of America, which has its headquarters near Madisonville, Ky.:

"We do have a high percentage of miners laid off. Mine closures around here started in 1979. From 1980 to now, we've had 4,000 miners laid off. Mines have closed or shut down."

It's not all due to high sulfur, he said. Coal transportation costs have had an influence, as well, in a generally softened coal market, but western Kentucky, with its high-sulfur coal, seems particularly hard hit.

Wants more study

The feeling locally is that mining companies are refusing to invest heavily to develop high-sulfur coal reserves until the shadow cast by possible legislation to control acid rain is lifted.

"On a personal basis, we think there should be more study put in it," Miller said. "On top of that, with the technology we have now, the sulfur could be eliminated by other measures [than switching to low-sulfur coal]. We think we should do that, rather than cause unemployment in the coal fields."

Robert Hendrix, of the UMW, said: "Dad mined coal for over 40 years. My brother is a miner, and my oldest son is a miner. It's a family tradition. We are proud to be miners. It's part of our heritage. Yes, sir."

"I think we're going to see some kind of legislation," Hendrix said.

There are 60,000 mining and support-industry jobs in the high-sulfur coal fields of the Midwest, Hendrix said, adding: "I can't see putting these people out of work."

Despite their huge size, coal mines come and go. New mines can open quickly; operating mines can be closed quickly. Mining responds to economics; economics responds to public policy.

Two of the three mines that provide coal for Wisconsin Electric's Oak Creek power plant are owned by the Pittsburg & Midway Coal Mining Co. of Denver.

When the Wisconsin Department of Natural Resources proposed a rule requiring utilities and industries to cut sulfur emissions to meet clean-air

standards, Barry G. McGrath, Pittsburg's vice president of marketing, flew to Wisconsin for a DNR hearing.

There he told the Natural Resources Board that 90% of the output of Pittsburg's Pleasant Hill mine in western Kentucky was committed to Wisconsin Electric, and that the new rule could threaten the contract and thereby the jobs of 365 miners.

There are a lot of miles between Madisonville, Ky., where this acid trail began, and Muskoka, Ontario, where, for the purposes of this story, it ends.

Many, many people

There are a lot of people along the way, including miners, railroaders who haul coal, utility vice presidents, electricity customers, foresters, resort owners, you and me.

In Ontario, a maple-syrup maker spoke proudly about how he was carrying on the tradition of three generations in the sugar patch. He described a lifestyle with a continuity that gave him an identity, a place.

In Kentucky, a coal miner spoke proudly about a tradition of three generations in the coal fields. He, too, described a lifestyle with a continuity that gave him an identity and a place.

Both feared the threat that acid rain posed to cherished traditions. But the issue, as it is perceived now, makes them natural adversaries.

How to turn off the acid rain

By Paul G. Hayes

Journal Science Reporter

CONTROL OF ACID RAIN will be expensive.

Removing 90% of the sulfur dioxide from just the Oak Creek power plant would cost residential customers of Wisconsin Electric — about 40% of Wisconsin's population — about 10% more for electricity, the utility said.

In a given year, Oak Creek may emit 140,000 tons or more of the stuff, more than twice as much as the next largest source in the state, Wisconsin Power & Light Co.'s Edgewater power plant in Sheboygan.

Of the 43 sources of more than 1,000 tons a year of sulfur dioxide in Wisconsin, the largest nine are power plants owned by electric utilities. The least of these emit 27,000 tons of sulfur dioxide each year.

Altogether, the total of 43 sources includes 20 power plants, including those at the University of Wisconsin — Madison and at the Milwaukee County Institutions grounds in Wauwatosa.

The remaining 23 are private industries, dominated by paper and pulp mills. The largest source of sulfur dioxide of these is Procter & Gamble's mill along the Fox River in Green Bay, at 24,000 tons a year.

Limits for utilities

The Wisconsin Legislature, sensitive to charges that Wisconsin is anti-business, did not directly address industrial sources of sulfur dioxide in its 1984 law requiring a cap on sulfur-dioxide emissions in 1985. It directed only utilities to keep their combined emissions under 500,000 tons.

"Utilities can't move out of the state," explained one insider.

But there were other reasons to concentrate only on the electric power plants. Of the total of roughly 653,000 tons of sulfur dioxide emitted each year by the top 43 sources, 78% came from the 20 power plants and 22% from the 23 industries.

Wisconsin ranks 16th among states for total sulfur emissions. By another measure — amount of sulfur dioxide emitted per unit of heat generated by coal-fired power plants — Wisconsin ranks among the five dirtiest states, said Paul Kozlar, of the Wisconsin Department of Natural Resources.

Last year, several acid-rain bills were considered by the US Congress. None passed, but similar bills surely will reappear this year. Even Wisconsin Electric's executives expect federal controls, if not next year, then soon after.

THE BILL THAT ATTRACTED the most attention called for a 30% reduction in sulfur-dioxide emissions from the 48 contiguous United States by 1993, or a total reduction of 10 million tons of sulfur dioxide.

The bill's goal was to be accomplished in two steps. In the first step, the top 50 sources of sulfur dioxide in the US would be required to cut their sulfur emissions.

Wisconsin Electric's Oak Creek power plant is one of these. If such a bill passed, a finger would be pointed directly at Oak Creek. It is not certain how Wisconsin Electric would go about meeting the requirement.

The bill would permit states to cut sulfur in any way they saw fit.

Keep in mind that the first of the eight boilers at Oak Creek is about 40 years old, old for a boiler, and that the deadline for reducing the sulfur would not occur until 1990 or so.

Keep in mind too that these boilers were designed to burn a particular coal, in this case, high-sulfur coal from southern Illinois, southern Indiana or western Kentucky.

The options would be to:

Phase out the boilers altogether and get electricity from other sources. From an acid-rain perspective, importing surplus power from a proposed, enormous hydroelectricity dam in Manitoba, Canada, is an attractive possibility. It is being studied.

Modify the boilers, if possible, to burn low-sulfur coal, or a blend of high-sulfur and low-sulfur coal.

Install equipment to catch the sulfur. Industry calls the process flue gas desulfurization, or FGD.

The final form of any regulations would affect the decision. But, for the purposes of this story, let's build an FGD system anyway, relying on data supplied by Wisconsin Electric.

First of all, there'd be a new island off the Oak Creek power plant in Lake Michigan, a big island, because there isn't any room on the present plant site for a sulfur scrubber.

Three pipes would lead from the present plant to the island, carrying the sulfur-dioxide-rich gas from the boilers. There the gas would be treated with two reagents, chemicals that convert sulfur dioxide to other compounds.

In this system, the reagents would be limestone, about 244,000 tons a year, and soda ash, about 21,700 tons a year. Limestone is abundant in southeastern Wisconsin; a quarry here may get the business. Soda ash comes from the western states.

If the power plant burned coal with 2.5% sulfur, if the plant produced an average of one-half of its theoretical capacity and if the FGD

1	Ohio		2,641
2	Pennsylvania	2,018	
3	Indiana	2,004	
4	Illinois	1,468	
5	Missouri	1,286	
6	Texas	1,274	
7	Kentucky	1,118	
8	Florida	1,093	
9	West Virginia	1,086	
10	Tennessee	1,074	
11	New York	942	
12	Michigan	905	
13	Arizona	898	
14	Georgia	838	
15	Alabama	767	
16	Wisconsin	636	
17	North Carolina	601	
18	California	446	
19	Virginia	380	
20	Massachusetts	344	
		Total	21,801
		U.S. Total	28,501

system were 90% effective, then this system would produce some 605,000 tons of waste a year.

This is the equivalent of 472,000 cubic yards. It would be mostly calcium sulfate. In other words, it would be damp, dirty gypsum.

Imagine a barrier 3 feet high and 3 feet wide stretching along the highways leading west out of Milwaukee. It would stretch to Mason City, about 270 miles away in the center of Iowa.

A parade of trucks would cross a causeway to the island every day to haul the gypsum off the island. Wisconsin Electric would add this mountain of gypsum to the 265,000 cubic yards of fly ash it disposes of each year on a 130-acre landfill on its Oak Creek property.

Scrubber operations would require hiring 165 full-time employees at Oak Creek alone, said Richard C. Bratcher,

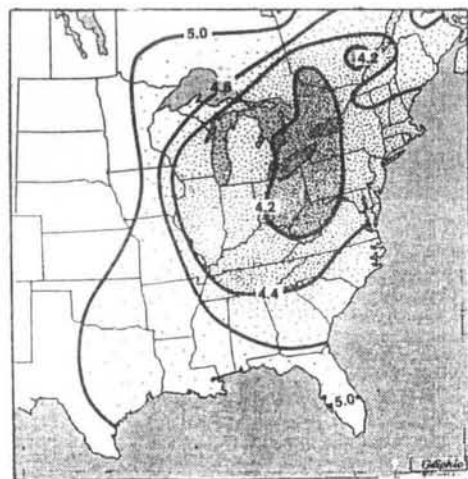
manager of environmental planning and projects for Wisconsin Electric.

What would it cost customers? Bratcher estimated that typical residential customers — households that buy an average of 500 kilowatt-hours a month — would pay about 10% more each month for their electricity.

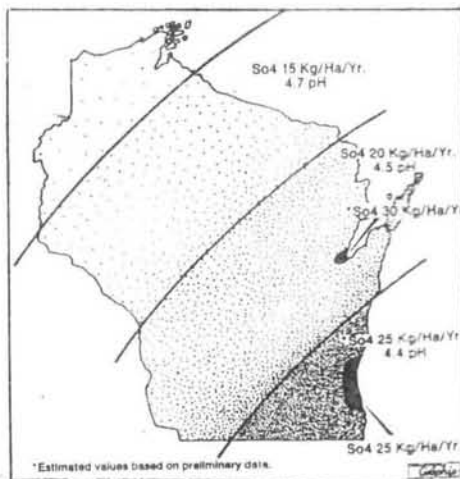
It is unlikely that Oak Creek would be the only Wisconsin power plant affected by a 30% overall reduction in sulfur dioxide. Meeting the second phase of the bill would require reductions at a dozen or so other power plants.

Wisconsin Electric's Port Washington plant and its Valley plant, south of Downtown Milwaukee, also might be required to scrubbers, Bratcher said. So would big plants elsewhere in Wisconsin.

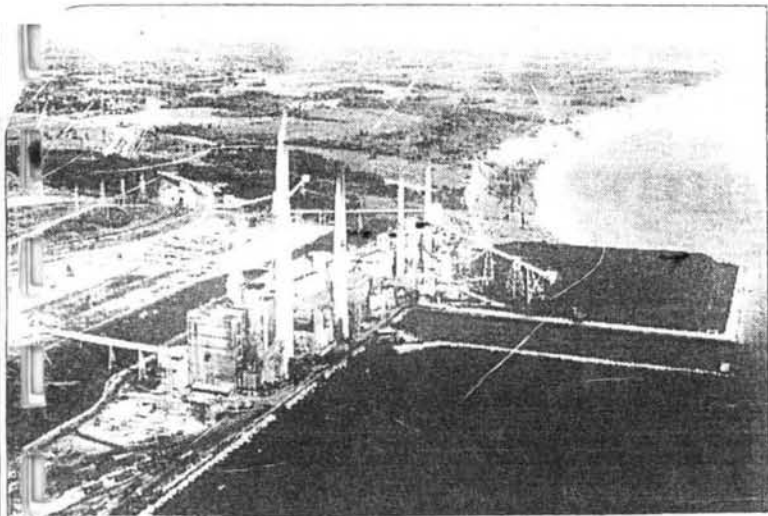
By no means has it been decided



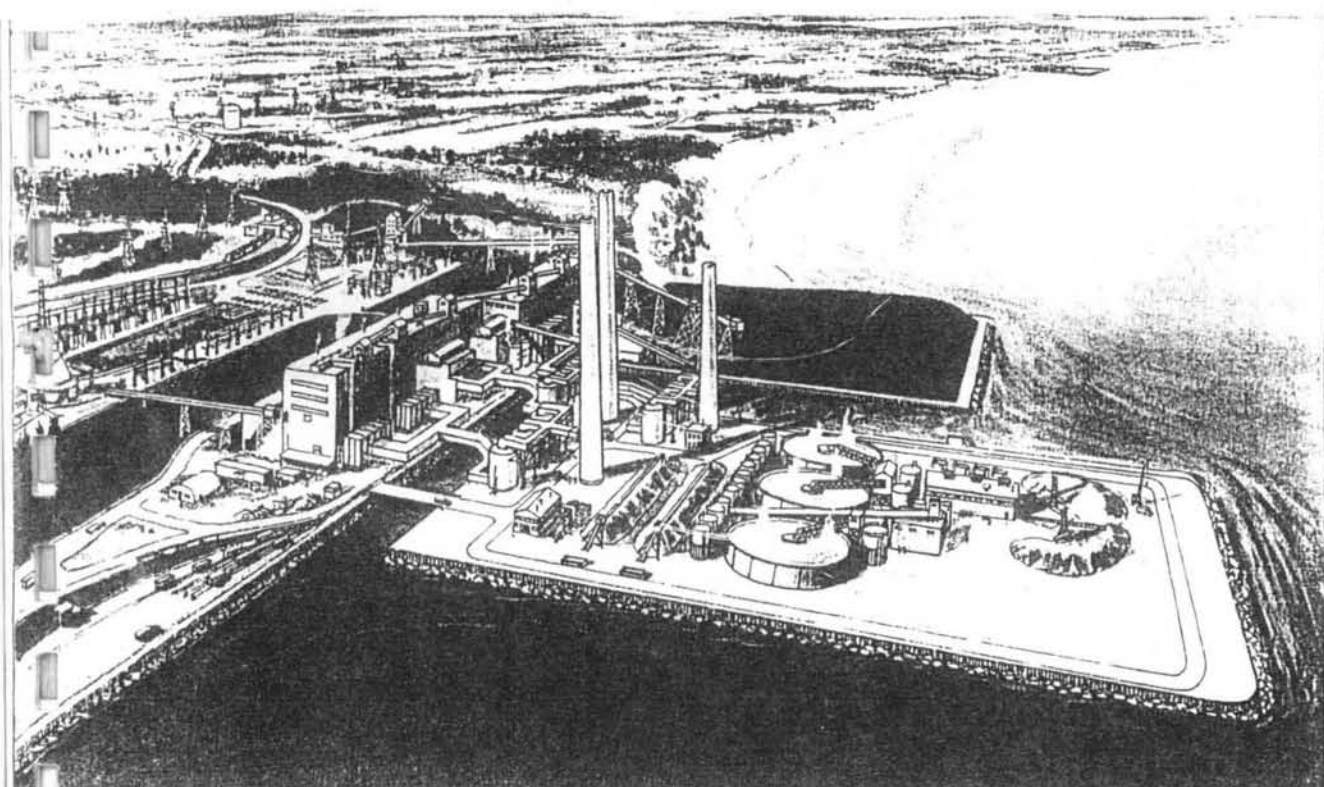
How acid is the rain? Wisconsin lies on the western fringe of the acid-rain belt with precipitation as acidic as pH 4.4. A core area covering parts of New York, Ohio, Pennsylvania, Kentucky and southern Canada has a pH level as low as 4.2. Precipitation with a pH lower than 5.0 is considered unnaturally acidic. Acid deposition across



Wisconsin is measured in kilograms per hectare per year (kg/ha/yr). Southeastern Wisconsin gets the most acidic rain with a pH level of 4.4 and a 25 kg/ha/yr (22 pounds per acre per year). The least amount falls in the northwest, which has a pH of 4.7 and 15 kg/ha/yr (13.2 pounds per acre per year).



Last year several acid-rain bills were considered by Congress. The bill that attracted the most attention called for a 30% reduction in sulfur-dioxide emissions from the 48 contiguous United States by 1993. One option facing sulfur-producing industries under orders to cut their sulfur emissions would be to install equipment to catch the sulfur. The industry calls the process flue gas desulfurization (FGD). If Wisconsin Electric's Oak Creek Power Plant (left) were to build the required equipment for FGD, what would it look like? First of all, there would be a new island (below) off the Oak Creek power plant in Lake Michigan because there isn't any room on the plant site for such a sulfur scrubber. Three huge pipes would lead from the plant to the island, carrying the sulfur-dioxide gas from the boilers. There, the gas would be treated with two reagents, or chemicals, that convert sulfur dioxide to other compounds.



by Journal Artist Marlo D. Cain

that sulfur scrubbing, likely the most expensive option, would be chosen.

More important, Bratcher believes that a major reduction of sulfur dioxide in Wisconsin would not have a detectable benefit on Wisconsin's environment, and certainly not one to warrant "the expenditures of ratepayer monies of several-hundred-million of dollars per year."

"This is especially so given the facts that no damage to Wisconsin's aquatic resources has been documented, and sensitive regions of northern Wisconsin receive only about one-fifth as much acid deposition as areas such as the Adirondacks."

It is true that Wisconsin is on the northern edge of the world's most intense concentration of sulfur-dioxide emissions. That is, we sit on

the northwest corner of the 31 eastern states that emit 17% of the world's man-made sulfur-dioxide air pollution.

Lucky us. Being on the outskirts — and not in the center — of this concentration protects us somewhat from acid rain.

Thus, less acid falls per acre in northwestern Wisconsin than in southeastern Wisconsin, and less acid falls in Wisconsin than in states east of here and in southeastern Canada.

YEARS OF INTENSE, state-sponsored research show that the scientific problem in Wisconsin is representative. Research continues to substantiate the theory that leads many experts to suspect cumulative, irreversible damage.

But lack of historical research and the difficulties of measuring harmful effects on soil, lakes, forests and animals — literally at a molecular level — create the scientifically uncertain atmosphere that leads to political stalemate.

Even with 50 years of information about lakes collected by pioneer lake scientists from the University of Wisconsin, trends are hard to prove.

But cross the border into Canada, and one enters a world of certainty.

It isn't that the scientific method in Canada is different. Scientists are asking the same questions in Canada that scientists are asking in the United States.

It is that Canadians have relatively more to lose from acid rain. They

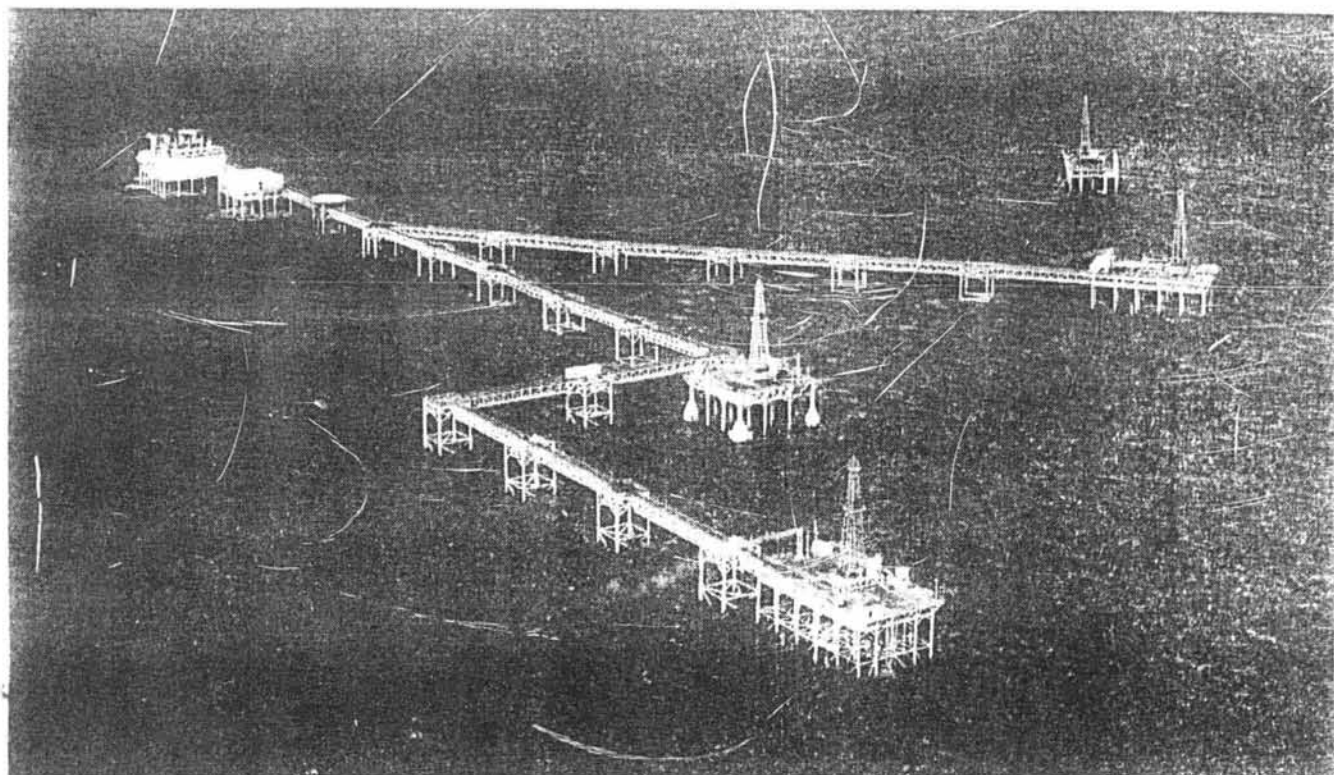
have lived with the effects of sulfur damage for decades. In Canada, acid rain is no longer a partisan political issue, but a national crusade.

Thomas G. Brydges, a chemist, coordinates acid precipitation research for the Ontario Ministry of the Environment in Toronto. He said:

"The bottom line is, you've got to stop doing it in the atmosphere. It's naive to think that you can put 25 million tons of sulfur dioxide in the air over North America and expect it to disappear.

"You can't take a parameter like [acidity], which influences every chemical reaction known, and knock it off center by a factor of 40 to 1,000 and not expect something to happen in the environment."

Much of nation's sulfur is squandered



Freeport Mineral Corp. mines sulfur from the world's largest offshore platform. The rig is in the Gulf of Mexico, off the coast of Louisiana.

MORE THAN \$10 MILLION blew out of the tall stacks at Wisconsin Electric Power Co.'s Oak Creek power plant last year.

At least 70,000 tons of sulfur were liberated from coal burned at Oak Creek and sent into the atmosphere as sulfur dioxide.

At November's price of \$147 per ton for pure sulfur, it was worth \$10,290,000.

It is largely ignored in the debate over acid rain that the main culprit of acid rain, sulfuric acid, is a valuable commodity and the most-used chemical in industrial commerce.

Probably because some of its compounds smell the way we imagine hell to smell — like very rotten eggs — sulfur has gotten a bad press for millennia.

Pure sulfur has no odor. Known as brimstone [literally, burning stone], sulfur is mentioned in the King James version of Genesis.

God rained down fire and brimstone upon Sodom and Gomorrah — and thereby caused the first documented instance of acid rain.

Valuable resource

But like so many pollution problems, much of acid rain, the pollutant, is a valuable resource that happens to be in the wrong place at the wrong time.

Because of its relatively low cost, sulfuric acid became one of the basic chemicals of the industrial revolution

the 19th century. Today it has thousands of uses.

Sulfur is used in the manufacture of fertilizer, in leaching ores, in treating metal, in making pulp and paper, in bleaching cloth. It is used in the production of dyes, food preservatives, photographic materials, sugar and textiles.

US industry produces huge amounts of sulfur, 13,052,000 short tons in 1980.

It is mined from beds of pure sulfur in an unusual way, both onshore and offshore, in Texas and Louisiana.

Freeport Mineral Corp., operating from the largest offshore platform in the world, pumps hot water down a pipe into a bed of pure sulfur. This melts the sulfur.

Compressed air is pumped down to the sulfur beds, forcing the molten sulfur up the pipe to be transported to Port Sulphur, La., about seven miles north, where it is prepared for commerce.

This method of mining is called the Frasch method, after its inventor. A few other onshore Frasch mines exist in the US.

Source of fertilizer

Nearly all of the sulfur from Freeport is shipped by barge to Tampa, Fla., where it is used in making phosphoric acid, a bulk fertilizer, from Florida's phosphate rock.

This is by far the dominant use of sulfur in the US. Because sulfur itself nourishes crops, it once remained in

the fertilizer as a bonus to be shipped northward and spread on the crops of the grain belt.

But shipping costs outpaced the value of the sulfur to farmers. Today, the sulfur remains in Florida in the form of calcium sulfate, or gypsum, a waste product that is disposed of in landfills.

In 1980, according to the US Bureau of Mines, about 54% of the sulfur in the US for industrial purposes was produced by the Frasch mining method.

The rest of it was removed from other resources. Much of the natural gas produced in the US contains hydrogen sulfide, a dangerous poison to humans. The nose detects it instantly; it is the gas emitted by rotten eggs.

For natural gas to be used safely, hydrogen sulfide must be removed. It is removed at gas processing plants, which converted it to almost 2 million short tons of pure sulfur for sale in 1980.

Similarly, sulfur is removed from petroleum at refineries, about 2.5 million short tons in 1980. Sulfur or commercial sulfuric acid also is recovered from metal smelters, where sulfide ores are processed.

\$2 billion wasted

By remarkable coincidence, US power plants and industries unintentionally caused 26,501,000 tons of sulfur dioxide to enter the atmosphere in 1980, or 13,250,500 tons of

pure sulfur, almost exactly the amount that entered commerce the same year.

Today, that sulfur, all of which was wasted, would be worth about \$2 billion commercially.

The obvious question: Why is the US wasting this non-renewable resource, particularly by spreading so much of it around as a harmful and costly pollutant?

The answer is not technological. The technology exists to capture wasted sulfur and convert it into the resource. By converting the sulfur in coal to sulfur dioxide gas, electric power plants accomplish a first step in the process that produces commercial sulfur or sulfuric acid.

The answer lies in cost. Even there, it can be understood only in terms of short-term gain.

In the world of resource exploitation, the rule is that industry always mines the high grade, easily accessible ores first.

Freeport Minerals and other companies that mine pure sulfur beds make a profit because mining costs are relatively low and the sulfur is immediately useful. Their profitability is aided by the usual tax benefits that are afforded resource companies, including a depletion allowance.

MAJOR OIL REFINERS are gas processors that remove sulfur from oil and gas sell on the market for a profit because the sulfur is relatively rich in those resources.

... of thumb among metal
is that the sulfur that is re-
d from stack gas pays for the
ding, but not the capital costs,
lfur removal. The reason: The
re" mined here is low quality.
From a resource perspective, high-
sulfur coal, coal that contains from
3% to 5% sulfur, might be thought
of as the lowest quality sulfur ore
being mined today.

So the problem at electric power
plants that burn high-sulfur coal is
that while sulfur is present in thou-
sands of tons, it still is thinly diluted
compared with the sources of com-
mercial sulfur.

Therefore, few utilities try to re-
cover sulfur.

Congress or individual states
advised policies to dramatically re-
duce sulfur emissions to control acid
rain, the method at hand would be to
fit existing power plants with sulfur-
capturing devices.

There are dozens of variations of
them. Basically, they fall into two
groups:

One reacts sulfur dioxide with
chemicals, usually calcium, and

produces a waste product that must
be disposed of.

The other produces commercial
sulfur or sulfuric acid and recycles
the reactant chemical.

The first group, called scrubbers,
requires among other things the
opening of limestone quarries and a
capacity to handle enormous
amounts of lime, or calcium oxide,
which is extracted from limestone
and neutralizes acid. Also, scrubbers
produce waste calcium sulfate, or
gypsum, in almost unimaginable vol-
umes.

Clean gypsum can be used in wall-
board. But utilities would produce
gypsum laced with other contami-
nants, including heavy metals. There-
fore, it would be useless. It would be
a gigantic, costly disposal problem.

Even so, with all their wastes,
scrubbers would be cheaper to install
and operate than devices that pro-
duced commercial sulfur, according
to studies done in 1983 by the Elec-
tric Power Research Institute, an
industry group.

THE STUDY CONCLUDED that
the cost of eight varieties of
scrubbers ranged from 14 mills

to 20 mills [a mill is one-tenth of a
cent] for each kilowatt-hour of elec-
tricity produced at a 1 million kilo-
watt plant.

The cost of six varieties of devices
that recovered the sulfur ranged
from 19 to 45 mills per kilowatt
hour.

The costs for the first system in-
cluded the cost of lime and landfill.
The costs of the second group that
saved the sulfur presumably were
offset by the projected sale of com-
mercial sulfur. But that price would
change constantly, according to sup-
ply and demand.

People who think of sulfur as a
resource deplore the loss of sulfur up
the stacks.

"Speaking as a citizen," said Har-
old Fike, president of the Sulfur In-
stitute, Washington, D.C., a research
organization, "you should recover
the sulfur."

Also, a 1980 study undertaken for
the US Bureau of Mines foresaw
shortages of commercial sulfur de-
veloping in the world and in the US
by the turn of the century.

By that time, it said, industrial so-
cieties may be looking to the tall
stacks of power plants, now the con-
troversial sources of sulfur the pollu-
tant, as sources of a valuable and
dwindling natural resource.

By that time, if nothing changed in
the current acid-rain picture, and the
US continued to contribute to the
problem at 1980 levels, we would
have squandered 260 million tons of
pure sulfur, and suffered its damage
as acid rain.

Meantime, when they think about
controlling acid rain, the US Environ-
mental Protection Agency and the
utilities concentrate on the lower-
cost systems that would produce
mountains of useless gypsum instead
of carloads of valuable sulfur.

Governments, being fragmented,
are shortsighted. The Bureau of
Mines sees sulfur, the resource. The
EPA sees only sulfur, the pollutant.

The public's interest is two-fold:
Protecting the environment and con-
serving the resource. A perfect policy
would get sulfur out of the atmos-
phere and into commerce, where it
belongs.

An Editorial

Acid rain action needed now

What does the sugar maple in
Canadian Marguerite Stimpson's
Ontario back yard have in common
with Wisconsin's Morgan Lake in
Florence County?

Both are suspected victims of acid
rain. No one can prove it yet, but the
indicators are disturbing. Stimpson's
maple is damaged at the top, the part
directly exposed to rain that Canadi-
an scientists say is increasingly acid-
ic. In Morgan Lake, the fish aren't
reproducing. Wisconsin scientists say
that's because the little, shallow
waterway is unhealthy acidic.

Perhaps neither of those small casu-
alties is cause for global alarm. But
Journal science reporter Paul Hayes,
in his recent series on "The Acid
Trail," noted other signs of trouble
here and there: studies indicating
that 3,500 of Wisconsin's nearly
15,000 lakes may be vulnerable to
acid rain; New York's concern over
200 lifeless lakes in the Adirondacks,
where deciduous trees are also dying;
the decline of the Black Forest in
Germany.

It may be, as some scientists sus-
pect, that many culprits are at work
in cases like these, acid rain perhaps
being the final insult that pushes
stressed resources over the edge.
Obviously, more research must be
done.

But President Reagan has used the
need for more study as an excuse for
inaction on the regulatory front.
Even when some of its own studies
have strengthened the case for ac-
tion, the administration has resisted.

Groups like the National Academy
of Sciences make a strong case for
preventive measures now in order to
stem what could be irreversible dam-
age to the environment. Natural sys-
tems can collapse almost overnight
when their capacity to withstand
environmental contaminants is ex-
hausted.

Just as the sources of the problem
are complex, there is no single solu-
tion. Rather, a diverse set of strate-
gies is in order, starting with nation-
wide curbs on sulfur emissions.

While waiting for the political and
economic struggle over that issue to
play itself out in Congress, Wisconsin
— the 16th largest emitter of sulfur
dioxide among the states — should
move beyond its current "cap" on
sulfur pollution and cut those emis-
sions by at least 30%.

The best approach, in our view, is
to let the utilities themselves decide
how to do that. Controls might in-
clude phasing out old, polluting
plants; increasing the use of low-sul-
fur coal; or installing scrubbers, de-
vices that wash the sulfur out of flue
gases.

Each of those approaches has its
problems, of course. For example, if
states cut back on burning high-sul-
fur coal, miners in the coalfields of
the Midwest will be thrown out of
work.

But it might be cheaper in the long
run for the federal government to
pay the cost of retraining or relocat-
ing miners (or subsidizing the older
ones) than to burden consumers with
the enormous expenses of (1) taking
the sulfur out of coal and (2) some-
how disposing of mountains of dirty
gypsum, a byproduct of the sulfur-
removal process. And assistance for
miners, along the lines of programs
for other displaced workers, *certainly*
makes more sense than sending
more than 13 million tons of pure
sulfur, a valuable resource, up the
nation's smokestacks each year.

For Wisconsin, an appealing alter-
native is the prospect of someday
importing surplus power from a pro-
posed hydroelectricity dam in Mani-
toba. Hydro power could be 27%
cheaper than electricity generated by
coal in Wisconsin, studies suggest; it
would certainly be cleaner.

In the meantime, consumers in
every state have at hand an old ally
in minimizing the ravages of acid
rain: energy conservation. Every kil-
owatt that need not be coal-generat-
ed is an investment in cleaner air and
healthier lakes and forests.

