

SYMPOSIUM ON ACID RAIN HELD AT MEGAWATT PARK

H.O. Egenes

(The following is a transcript of the taperecorded joint discussion held by the Transvaal Branch in conjunction with the Coal Club.)

Dr Annegarn

This is the first combined meeting between the National Association for clean Air and the Coal Club. The latter are responsible for getting the coal out of the ground and the former organisation for getting the resulting pollution out of the air.

Dr. Bruce Wells.

I want to sketch the various aspects of the problem of acid rain. The sulphur cycle is a natural one which takes place in the atmosphere to which the large amounts of sulphur emitted from industrial sources contribute. Roly van Gogh of the C.S.I.R. will talk about sulphur-dioxide concentrations measured in the Eastern Transvaal. Once free acid has been formed in the atmosphere, it can either be neutralised or continue to exist as acid. Ammonia which is formed by natural processes, can act as a neutralising agent. The acid may therefore exist as a mixture of acids in the vapour form, or neutralised. Miss Margaret Böhm will talk later on the complexities of measuring acid rain. It is also possible for acid to be deposited on the soil in a dry form without being precipitated as rain. The words "Acid Rain" are extremely emotive and talk of the effects of acid rain have grown up out of proportion. Acid deposition is however of concern whether it reaches the ground in wet or dry form. Finally Dr. Thompson will address us on the possible effects of acid precipitation on the soil. As he will explain there are many processes in the soil which themselves may far outweigh the effects of acid rain. Work done by the C.S.I.R. also involves the effects of other substances such as Sulphates, Nitrates, Chlorides, Fluorides and that of particulate matter mainly in the Eastern Transvaal.

Miss Margaret Böhm

"I shot an arrow into the air and to my surprise it stuck. The rain did come, the arrow fell, all covered with black acidic muck".

Before we can answer the questions currently being asked about acid rain we need to know what is "acid precipitation". After a decade of research in Europe and in North America the subject is still shrouded in mystery. Particulates in the atmosphere produced naturally and by man may be deposited on the earth by the wet or dry processes. Dry deposition is simply the gravitational settling of particles to the earth surface. Deposition rates are particularly susceptible to three parameters, atmospheric stability wind speed and surface characteristics.

Despite popular belief, dry deposition contributes significantly to removal of particulates from the atmosphere. Wet deposition on the other hand can be divided into rain out and wash out.

Hygroscopic particles in the atmosphere act as condensation nuclei and cloud droplets mix with particles during collision. This gathering of particles in a cloud during rain, hail or snow formation is called rain out. The actual washing of the atmosphere is called wash out. It is obvious that the chemistry of wet or dry deposition depends upon the chemistry of the particles deposited.

It is for this reason that the popular definition of acid rain as rain having a pH of less than 5,6 is no longer accurate. The magical number of 5,6 is no more than the equilibrium between distilled water and carbon-dioxide. Since atmospheric water vapour requires hygroscopic nuclei around which to condense, cloud water droplets, in this respect do not resemble distilled water. Atmospheric chemistry depends upon the chemistry of the hygroscopic impacted and absorbed particles.

Since there is an abundance of hygroscopic nuclei in the atmosphere that are naturally acidic a wet deposition of below 5,6 pH will normally result. Should however wet deposition be formed around nuclei of a basic nature the resulting pH will be somewhat higher. This reasoning implies then that there is no universal background pH for rain water. The question becomes then, what is acid precipitation?

Atmospheric chemists such as James Galaway define it as a wet or dry deposition problem where the acidification of the precipitation results from a man made process caused primarily by the combustion of fossil fuel by heavy industry. This definition was compiled after many years of research on the chemical composition of fall out, particularly rain water. Scientists agree that acidity of deposition downwind of industrial complexes is controlled by sulphate and nitrate ions. Small quantities of sulphate and nitrate are emitted into the atmosphere in this form, but the amount is minimal. It is therefore suspected that the amounts of sulphates and nitrates measured result from chemical transformation from the oxides. These oxides are the primary emissions, and it is important to assess these when deciding whether the deposition is naturally acidic or not. This is because oxides of sulphur are produced naturally by bacterial decomposition of organic matter, by volcanoes and by the reduction of sulphates in oxygen deple-

ted waters. On the other hand, the natural origins of nitrogen oxide are thought to be chemical decomposition of nitrates during lightning episodes.

It is evident however that increased industrialisation especially the burning of fossil fuels is responsible for most sulphur and nitrogen oxides. In an urban environment motor vehicle traffic is a major contributor to nitrogen oxide emissions. Global budgets for background sulphur and nitrogen oxides have been made but few reliable measurements exist. The amount of industrial sulphur and nitrogen oxides emitted can be calculated and the number of other acidic precursors can be estimated but not enough is known about the gas to particle conversion mechanism to accurately predict the amount and nature of fall-out. There are a large number of ways that gas to particulate conversion can proceed.

The conversion of sulphur di-oxide to sulphate seems to occur along both homogeneous and heterogeneous reactions. In homogeneous reactions the sulphur-dioxide molecules are oxidised in the gas phase by strong oxidising radicals. These oxidising radicals may result as intermediate products in photo-oxidation with carbon or nitrogen oxides. Other factors that are important are temperature, solar radiation, dew point and the absolute concentration of the reactive components. Heterogeneous reactions on the other hand involve gaseous, liquid and solid phases. Three important mechanisms contribute. Firstly the catalytic oxidation of the sulphur di-oxide with water droplets by transition metals. Secondly oxidation of sulphur di-oxide in liquid phase by strong oxidants such as ozone and peroxide. Thirdly, oxidation of sulphur-dioxide upon collision with soot particles or elemental carbon.

The chemistry of atmospheric nitrogen is not well understood, but the various processes by which nitrogen di-oxide is converted into acidic end products are very important.

Various gases such as sulphur di-oxide, chlorine, nitrogen oxide and particulates exist both naturally and artificially. Once in the atmosphere the gases are converted to particulates at a rate determined by the catalysing effects of solar radiation, ozone, transition metals and oxidising radicals. By the time that the gas to particle conversion is complete aerosols may have travelled hundreds of kilometers. How and when these microscopic size particulates are deposited on the ground depends upon the height of the emission meteorological conditions and surface characteristics. Having established the contribution of heavy industry to acid forming emissions, if we stop burning fossil fuel, will we still have acid rain? To answer this would have been easy if the teachings of Robert Angus Smith in 1872 had been comprehended. In common however with all great scientists he was ahead of his time. Scientists were preoccupied with the industrial revolution and the making of air pollution which was seen at the time as an indication of progress. There were therefore no reliable background measurements of deposition occurring before industrialisation in the areas of concern today.

All we can do is to monitor present eco-system loading to determine which substances are causing the acidity and what the source emissions are. This sort of research has been in progress for at least a decade in Europe and in the U.S.A. and the results are most contradictory. This is the reason that acid rain is such a controversial subject in the literature. It was only in 1976, some 104 years after Smith's detailed report that scientists took a long hard look at wet and dry deposition. I would like to elaborate on the problems experienced with wet and dry monitoring of deposition. Considering dry deposition first, many diverse methods have been used to assess this largely because of the problem of contamination of the samples. The cheapest and most frequently used technique is the deposit gauge. This consists of an open surface and a container filled with water situated at a certain height above the ground level and left out in the atmosphere for a prescribed period of time. The major criticism of this approach is that the use of artificial collecting surfaces does not simulate the dry deposition of particulates and gasses on dry surfaces. There are also problems related to sulphur preservation and in preventing neutralisation by atmospheric ammonia. These devices are useful for pilot studies.

Present research trends are to ascertain the particle size distribution at various heights above an area of uniform surface type and impactors are being used. Using micrometeorological data and wind speed as well as atmospheric stability, as well as aerodynamic surfaces, data can be calculated as averaged over a known time interval. This enables the dry deposition flux to be determined. The method however is complex and depends upon the accuracy of laboratory and field experiments to obtain deposition flux from known particulates under known conditions and surface

Regarding wet deposition, scientists have been determining the chemical composition of rain for years, but the major problems encountered relate to the collection and storage of samples rather than the analytical techniques. The first problem is to collect a representative sample. The instrument must be constructed from non corrosive material and splash over must be prevented. The area of the sampling orifice however must be large enough for sufficient volume to be collected to facilitate full chemical analysis. If the main substances of interest are organic then the collecting surfaces must be glass. This is because plastic surfaces are very porous to organic material. If on the other hand inorganic material is of interest, then plastic surfaces must be used as glass is porous to inorganics.

Cleanliness is of the utmost importance and it is wise to collect the samples on an event basis. The collectors we are using are also the most popular in America. The buckets are sufficiently far apart to prevent splash-over and the movable lid is springloaded so that it sits down on the wet bucket preventing any dry deposition from entering during dry episodes. The moisture sensor detects the beginning of the rain event, and its base plate is heated so that once the rain stops evaporation of the moisture proceeds faster and you get a limited open time. Having collect

the sample the problem becomes to preserve its chemical composition. Various researchers have noted significant differences in the pH measured by site operators and those recorded in the laboratory. For years this discrepancy was put down to site operator negligence, but pH will change with time.

At a pH below 4,5 it is expected that organic acids contribute very little to the acidity of the sample. Between a pH of 4,5 and 6 the situation is very different. It is suspected that organic acids now play a very important role. Biota bacteria and viruses are washed out with rain and will consume organic acids and so the pH will gradually rise until there is no more organic acid left. The pH will then remain stable. At above 7,0 the acidity will actually increase and it is suspected that this is due to carbon-dioxide absorption. These results agree with those obtained by William Keen and James Gallaway but may not be representative of samples collected everywhere. It is evident however that pH must be measured immediately after the rainstorm and not within 24 hours as specified overseas. Regarding the chemical composition this will remain stable up to 6 months if the sample is stored in a closed container and kept in the dark at 6 degrees centigrade. Organic acids may reasonably be preserved in chloroform or freezing. When the sample melts however there may be loss of organic acids as freezing does not kill the hungry biota. Many people measure only pH and do not consider the chemical composition. This invariably results in incorrect conclusions. Measurement of pH on its own is useless in drawing conclusions on the acidity of precipitation. It is vital to know which acids are the main cause. To illustrate this, during experiments at Stellenbosch samples with pH of 5,08 were collected. Analysis showed that sulphate and nitrate contributed only 2 1/2% to this acidity. Chlorides from sea salt contributed about 15% of the acidity and it is not known what was responsible for the rest as we were not set up to analyse for organics.

My advice to scientists when examining acid rain then is to:

Measure pH immediately after rain storm. Remember that rain water has a very low ionic content.

Preserve the sample by chloroform and freezing and get it to the laboratory as soon as possible for a full chemical analysis. If you follow this advice then much of the sensational and erroneous reporting will disappear.

One last plea, let us learn from the wisdom of the Europeans and the stupidity of the Americans. When setting up monitoring networks, ensure that all the data can be integrated. The study of acid rain is a very interesting one.

Dr. Thompson

When acidification of the soil is being considered there are far greater problems than those caused by acid rain, due to natural phenomena. All soils are leached to some degree by rain water, the degree of leaching being dependant on many factors. For instance a light shower may not cause leaching

at all, while a heavy shower will do so. In considering the degree of leaching the nature of the parent material is of utmost importance. A quartzitic sand with very little clay content will be more subject to leaching than a clay soil derived from dolerite with more base releasing materials. The underlying strata is also important as a well shattered material will allow internal drainage being more subject to leaching than granite material. Topography also plays its part in that a heavy run off from uplands will result in heavy leaching of the lowlands. The presence of weathered products in the upland soils however may result in deposition in the low lying areas. The pH of soil varies greatly from place to place but generally the higher the rainfall, the lower the pH of the immediate subsoil. Due to the presence of base material in the topsoil, it is more resistant to leaching than the subsoil which has basic material abstracted from it, not only by the vegetation but by the water passing through. Due to the buffering effect of aluminium in clay soils, the lowest pH obtainable is 3,8. This is because there is a limit to the availability of hydrogen ions in rain water. Acid soils are also caused by the replacement of calcium, sodium, and magnesium in the clay complex by hydrogen ions. Various attempts have also been made to estimate the amount of nitrogen deposited in natural rainfall generated principally by lightning. Estimates range from 3 to 6 kilograms of nitric acid deposited in this way, per hectare per annum.

When the soil acidity drops below about 4,7, there is a tendency for manganese, which is present in all our soils to become mobile and available to plants resulting in a reduction in yield. Below a pH of 4,2 toxicity symptoms increase due to the presence of aluminium. This is a major problem in South Africa, especially in the Eastern Transvaal and in the Natal midlands. In the Eastern Transvaal where rainfall is relatively high, the natural pH of the soils is between 4,0 and 4,7 and liming is a regular feature. This is a typical maizeland area, and liming has to be practised to overcome the magnesium and aluminium problem. Low pH also reduces the availability of phosphates. It may be thought then that acid rain will have an appreciable effect on our maize crop especially downwind from the power stations. This however does not happen. Sulphur is an essential ingredient in plant growth and very few instances of sulphur deficiency have been recorded in South Africa, unlike Zimbabwe where it is mandatory that all fertilisers contain at least 6,5 percent elemental sulphur to overcome sulphur deficiency. Sulphur deposition is therefore beneficial in South Africa.

To put acid rain in perspective, immediately you plough soil the pH will drop due to the mineralisation of organic nitrogen and the release of ammonium salts to the atmosphere. Plants take up the nitrogen and leave the acid radical behind leading to acidification of the subsoil, from the time that the soil is cultivated. Woodland soil will invariably drop in pH on cultivation. When farmers apply nitrogen fertiliser this also has an acidifying effect, particularly when you realise that 100 kgs of ammonium sulphate requires 75 kgs of limestone to neutralise it. Normal additive to Eastern Transvaal soils is 100 kgs of elemental nitro-

gen per hectare. This is of a different order to that ascribed to acid rain.

It has been claimed that forests in Europe are dying because of acid rain. Here however they have been experiencing low levels of acid rain for some 60 years and are only now beginning to lime the soils. On the other hand in most areas of the Eastern Transvaal liming is carried out as a regular practice. Our institute intends to investigate the possible effects of acid rain on vegetation, but this will be very difficult due to the masking effects of other acidifying agents.

When coal was about 25 cents a ton, the extraction of in situ coal was only about one third. These mines have filled with water which has a pH of about 2,4 due to the oxidation of pyrites and the water is draining to the banks of streams where it is killing the vegetation. There are about 800 sq. kilometres of mine dumps in the Witwatersrand area. Sulphates in these mine dumps result in acid run off. This material is being reprocessed by Ergo for residual gold and uranium and some 1500 tons a day of rock sulphate is being recovered in the process.

Mr. Roly von Gogh

Research is more biased today towards the sources of acid rain particularly on the Eastern Highveld. The meteorological factors are something that we have been largely unable to deal with, these fall into the realm of long range transportation. We will first of all look at the various sources, that have been indited as being presursors of acid rain. The primary aim of meteorology is to determine where and in what quantities pollutants will be transported. In other words the relationship between the source and the actual concentration. Of the coal burnt on the Highveld, two thirds is burnt by Escom, by numerous power stations in the area. To put this in perspective; if all these power stations run at full capacity we will get introduced into the atmosphere two megatons of sulphur di-oxide per annum. On a daily basis it will amount to 5000 tons per day. Because of the load factor however a realistic figure is of the order of 3000 tons per day. To give an analogy to this at standard temperature and pressure it will occupy something like 400 olympic sized swimming pools. The other major source of sulphur di-oxide is undoubtedly Sasol and according to reliable information they emit something of the order of 300 tons per day of sulphur di-oxide. There are numerous other smaller contributions from other industries. Besides these active sources of acid rain precursors, resulting from industry, there is a number of other sources in the Eastern Transvaal that are non productive in nature, these are the burning discard dumps which litter the Eastern Highveld. While their contribution is estimated to be of the order of 350 tons per day these pollutants are emitted at low level relative to power station emissions occurring at an effective height of 500 metres. The consequences of these emissions at different levels is very difficult to quantify but the total emissions are of the order of 3700 tons per day. These are at least equivalent to the same emissions

over the same area as parts of the U.S.A. Sulphur di-oxide is obviously dispersed in a number of ways, I have mentioned the effect of stack height, but the effect of meteorology is possibly the prime determinate once the emission is released. Under certain conditions we get stable plumes with very little mixing principally during inversion conditions. These plumes can travel up to hundreds of kilometres in a relatively undiluted form. When conditions become unstable, pollution will become mixed throughout the mixing layer. Within the confines of the area a pollution front may be established; depending upon the prevailing winds in the area of interest. Emissions at high level can be entrained directly into the cloud base, in this way it is easy to see the relationship between the transport of the pollutant and its assimilation into the cloud. On other occasions the transport may occur over hundreds or thousands of kilometres, and its fate is far less clearly defined. Having all these various sources emitting at various levels and under various conditions what concentrations can we expect over the Eastern Highveld? The result sounds horrifying and very high concentrations can be expected. In fact the concentration by world standards over any averaging period are in fact low. As a guideline the U.S.A. primary standards for the annual mean and the 24 hour mean are given. The three hourly mean of 500ppb was recorded at Grootpan on several occasions, which was the upper limit of the instrumentation. The concentrations within the area that we are interested in are very low while the tonnages emitted are apparently astronomically high. Either the pollutants are being transported out of the area, to be deposited elsewhere, or there is a very high rate of conversion from primary to secondary pollutant within the area. Fortunately Dr. Wells has for some time been measuring secondary pollutant, but I suspect that most of the emissions are being transported out of the area. The concentration being experienced at the various sites at which sulphur di-oxide is being measured is due largely to a small area in the central region of the South Eastern Transvaal and this is where most of the discard dumps are situated. Further evidence of the fact that the low level pollution being monitored at approximately three metres above the ground level is being constrained within the area, is that the highest concentrations recorded at the most easterly site are attributable to westerly winds while the contributions at the westerly sites are due to the easterly winds. It appears therefore that no significant low level sources exist outside the Eastern Highveld region: Further evidence that low level sources are responsible for much of the pollution comes from the annual variation of gross meteorological parameters such as the inversion frequency. Most power station emissions occur above the surface inversion. The pattern to be expected between low level emissions and SO₂ concentrations is low windspeeds, high concentrations, high inversion frequency high concentrations.

How do these concentrations compare with other heavily polluted regions of the world? The north eastern areas of the U.S.A. is an example and we are experiencing similar concentrations over all averaging times as are being experienced in the U.S.A., and the U.S.A. has a proven acid

rain problem. Our problem is that the bulk of the pollution is being transported at high levels in the atmosphere. To attempt to estimate therefore the areas of influence of conversion of SO_2 , is we have to know in great detail the vertical variation of the wind speed and direction, which is well known to vary greatly both in space and time. Up to now we have not had the means to investigate the vertical variation in temperature or wind speed on a continuous basis. Technology has fortunately caught up and today such measurements can be made. It is however extremely expensive to mount a project to determine the long range transportation and conversion of pollutants. Surface wind directions cannot be used as an indication of the behaviour of high level winds either in time direction or wind speed. The problems are the high degree of variability in nature of the parameters we are studying, the costs involved, and the manpower needed.

Some of the expertise required is: meteorology, climatology, synoptic scale circulation, cloud dynamics, cloud chemistry, mixing depths, dry and wet deposition rates, chemical variations along pollution trajectories as well as the rates of transformation. At the C.S.I.R. in the 1977 pilot investigation, the long range transportation of air pollutants was undertaken, but as is the way with many such grand schemes it failed due to lack of finance and the necessary skills. There can be no doubt if the problem is identified and if the authorities recommend desulphurisation of flue gas emissions, the costs to the consumer will be astronomical. Flue Gas Desulphurisation plant for a 3600 MW station to remove 70 per cent of the SO_2 will be about 500 million rand. Over the next 10 years a doubling in the amount of SO_2 can be expected. By careful siting and a better understanding of the meteorology we may be able to save a great deal of money in the future. It is advisable that the monitoring that Escom has started be continued, and that far greater emphasis be placed on the establishment of the relationships between the emission and the concentrations in the environment.

Dr. Bruce Wells will now tell us some of the reasons that we may get acid deposition in the area that we are considering.

Dr. Bruce Wells

I am now going to tell you about another activity of the C.S.I.R. We are currently running 10 monitoring stations in the Eastern Transvaal area where we collect filter samples of the particulates in the area. These are double filters, the first showing particles bigger than 8 microns in size, while the second collects samples bigger than 4 microns. We have collected daily samples over a period of six months and have analysed each of these samples. The most important result is the sulphates but we analyse nitrate, chloride, fluoride and phosphate. The high values are seen to be concentrated around Witbank and Middelburg in the North. The measurements constitute about 80,000 determinations and at the moment we are drowned in information that needs detailed evaluation. The coal dumps are monitored at ground level and are localised within the power genera-

tion area. For all we know we may be only measuring sulphate generated by the coal dumps and not by the power stations. The network should therefore be greatly expanded to include long range transport down wind. At the present moment it takes one technician from 05h00 to 21h00 to service all the sampling points. To get some perspective to the concentrations reported, the only sulphate levels laid down in the literature is the Californian standard of 25 micrograms per cubic meter. The peak values at Witbank are close to these figures although the mean values over the month are lower. The 25 microgram figure is set for a 24 hour period. I suspect that the Californians have set their limit for visibility reasons.

This huge amount of data needs evaluating, before a report can be made to the Department of planning who sponsored the project, but in the meanwhile we are preparing for a further year's work. One point to be noted is that although the project terminated in November 1983, we collected further samples in the Witbank area during the summer months, and we have come to the conclusion that there at least there is not a great deal of difference between the pollution experienced in winter and summer. It had long been believed that the South African pollution problem is essentially a winter one, but this does not seem to be the case. The reason is probably that in summer dispersion may be improved but the mechanisms for conversion from SO_2 to sulphate are enhanced.

I want to introduce an analogy now between acid rain, acid deposition and pollution as a whole. In a normal business there is a bookkeeper, accountant and auditor. These three observe all the financial aspects of our financial institutions. This is accepted in society. There always however seems to be a feeling of suspicion when a chemist or physicist gets out their gear and starts taking measurements. I would like our work to be regarded essentially as auditing another aspect of our life, where the environment is a business being run well or not well and we must ask if we can give an account of what is happening. At present we do not have the means of giving a full account. To illustrate this, if you look at the SO_2 concentration it does not tell us the whole story by any means. For instance if you know someone has 1000 rand in the bank you have no way of knowing what is passing through that account, the deposits and the withdrawals, unless you know that you don't know the state of the account. It is useful to measure SO_2 and sulphate but we need to evaluate the whole picture, to see where the gaps are in what we are not measuring. At this moment we are not measuring over a wide enough area of land, as acid rain could be transported over hundreds of kilometres, if we find that it is not a real problem then we can save ourselves a lot of money. We also need to measure data at different altitudes in the air. Finally we have to come down to the soil and the plants living in the soil. Are these being damaged or not? We do have other major inputs to the soil which acidify it. A fact that bothers me slightly is that a farmer who is growing mealies may lime his land, but the farmer who is grazing cattle on the open veld may take no such precautions. Acid rain could be a pro-

blem to some but not to others. Secondly there is the problem of synergistic effects. It is all very well to design an experiment to expose a plant to a given amount of acidity, but in mother nature we have a host of predatory organisms, which, given acid rain will give them an opening and we may end up with a plague of rust or some other problem. The question is, do we have the information to really balance the books and should we make an effort to balance them? My request then is to consider the areas of the problem that we have not really dealt with.

Discussion and questions

Funke — (Water Research Commission). Dr. Thompson made the statement that acidification of the soil is partially due to acid precipitation. In Western Germany I was told that 97 per cent of acidity in soil (covered soils) can be attributed to decaying organic matter and only 3 per cent to acid precipitation. This is a revolutionary statement. Dr. Thompson agreed with these remarks and drew attention to his remarks regarding the acidifying action of crop cultivation, and a considerable amount of acidification comes from the breakdown of organic matter, and this is a continuous process. I have read a German report that stated that some forests are dying and this has been blamed on the long term effects of acid rain.

Tudhope — (Escom). How did Roly von Gogh get 3000 tons of SO_2 ? Which I find rather high. Secondly, a precursor that has been mentioned to me by the Dept. of Health is the emission put out by black townships. The SO_2 was worked out on the sulphur in coal and the units sent out by the major stations. Mr. Tudhope —, very roughly the Eastern Transvaal Power Stations burnt about 40 million tons of coal at one per cent sulphur, ie. 400 000 tons of sulphur, how much gets up the stack I don't know. You effectively double the sulphur weight. There is a lot of debate at the moment on the conversion of sulphur to SO_2 , but it is considered to be 95%. There is no knowledge of the amount of SO_2 generated by the townships.

Dr. Annegarn — (Wits. University). There is a combined effort by the C.S.I.R. and ESCOM and the Wits. University on the pollution in SOWETO, and this program is to be expanded.

Does the panel know how much of the SO_2 is being exported to other countries? No we would only be guessing at that. (Mr. Pearce Escom). Perhaps our water resources are more at risk, than the land, from pollution introduced in concentrated doses than from pollution introduced from air from widely dispersed sources. If we desulphurise the material coming out of our flues a chemical product is produced that has to be handled and dumped into slimes dams and these are a continuing source of pollution into our water. It will be very difficult to handle the resulting water pollution.

Dr. Errol — (A hydrologist). One thing that does come to light is the problem of finding deposition gauges, the one

deposition gauge that we are inclined to overlook is the Vaal Dam Catchment. Looking at that gauge where the total dissolved solids are measured, it is clear that the is going up and that is not all attributable to the drought. Looking at individual parts of the catchment we have a monitoring station on the Waterval River and at that point we note a situation in terms of sulphates. Part of this is due to point sources and part due to the so called diffuse sources including atmospheric. The overall situation is illuminating in that from a paper by Mr. Funke we have the potential solids tonnage that is busy going up the stacks annually up to 1991, excluding the power stations on the Witbank coalfields, which probably do not contribute to the Vaal catchment area. Looking only at the Highveld and South Rand coalfields the tonnage climb from 1970 from about 181 000 tons to 1980, 600 000 tons and based on planned power stations by 1991, 1 600 000 tons. By way of comparison the natural salt yield of the entire Vaal Dam catchment based on water quality dated prior to the establishment of power stations in that catchment is of the order of 200 000 tons of soluble solids including SO_2 that has been oxidised into SO_4 and bearing in mind that the NO_x is one third of the SO_2 . What the fate of the tonnage going up the stack is we don't know, but we do know that under 1980 conditions we are putting up the stacks three times the entire natural yield of the Vaal Catchment and by 1991 this will increase to eight times the annual average salt yield of the Vaal Dam catchment. To give you an idea of the long term problem produced to our water resources I have been involved in some computer modelling and based on assumed catchment characteristics similar to catchments in the Southern PWV area. These show that if in year zero the natural salt input into the catchment would be suddenly doubled, ie. the natural yield to the catchment is 13 kilograms per square kilometre and this is doubled to 26, it would take several decades before the total dissolved solids concentration in the run off water would double. In the first few years you would notice very little change. To compound that further, we have the situation, that the simulation of total dissolved solids concentrations in the natural run-off of the Vaal Dam catchment in the long term taking into account hydrological effects, ie. during floods there are generally lower TDS concentrations, during the period 1970 to 1980, we had some extremely wet conditions, under natural conditions the TDS concentrations in the water should have dropped but in fact it went up. Part of the rise in one period is due to the drought. Looking at another aspect, a very costly one to the economy since Vaal Dam is the major source of supply to the PWV area, a high TDS in the water costs industry, including ESCOM, a great deal of money.

So far as the analysis that I have done for the Vaal Dam catchment I totally ignored the point sources.

Mr. Funke — We must be a little cautious because the one measuring point is measuring acid mine drainage from the Evander Kinross area. I did some preliminary survey at Waterval and it was quite clear that between 1972 and 1974 a tremendous amount of sulphate was going into the Vaal

Dam Weir of the order of 75 000 tons of sulphate per annum. The load for 1980 – 1982 was of the region of 7 000 tons. This could have been from any source, farming activity, acid mine drainage, afforestation, acid precipitation, in any case the concentration at present is of the order of 16 milligram per litre which is low if compared with the Vaal Barrage where concentration is 300 to 400 milligrams per litre of sulphate from gold mining activities.

Question: I do not think there is much danger from inhaling the acid but one is concerned about the effect of acid leaching on the food that we eat. We have two epidemics in this country, one endemic and one epidemic. These are heart disease in whites and increasing blood pressure in blacks. At the Pretoria University we are examining the possibility of other causes of heart disease and one thing that seems to be cropping up is a change in the enzyme reactions caused by certain vitamins. The effect of this precipitation of acid will mainly be felt in the Eastern Transvaal. The food pantry of South Africa is mainly the Western Transvaal to the Eastern Free State. Could it be expected that this high acid precipitation would adversely affect these areas.

Dr. Thompson – We have no information on the effect on vitamins but what I can say is that the further west you go the more highly saturated the soil becomes and any acid rain that fell there would be neutralised by the soils.

Margaret Böhm – We don't know if we have an acid rain problem in these areas, but research in the U.S.A. has shown that the main problem has been the migration of alumina into aquatic systems. The aluminum ion is highly toxic on the gills of fish causing a mucous layer and the fish die, there may also be problems with other heavy metals being absorbed into the fish. To date there is no evidence of direct acid rain effects on humans, but all literature is concentrated on forestry and aquatic systems.

Mr. Bulley – Mr. von Gogh stated that if we were to supply flue gas desulphurisation on a 3600 MW power station, it would cost between 500 and 600 million rand. These figures are too high and a better figure would be 150 million rand, which is still a lot of money. Reading through the literature the other day about SO₂ to SO₃ conversion, the statement was one per cent per hour in the U.S.A. What I would like to know is have we agreed rates for conversion in South Africa, bearing in mind that we have high ultra-violet radiation, a high altitude and we have from our Ferrometal industry a large amount of iron and chromium catalysts.

Margaret Böhm – I am not too sure of SO₂ to SO₃ but I have been involved in a project to calculate SO₂ to SO₄ conversion rates and preliminary data is showing about 0,2 per cent. The various catalytic effects depend on the presence of moisture and we are lacking in this.

Mr. Dowles – The man in the street is more likely to grumble during times of temperature inversion and under these conditions the plume from the power station will mix with the vapour from the cooling tower and consequently produce a faster conversion to SO₄. Some years ago, on a simi-

lar question at a similar N.A.C.A. meeting, Dr. Humphries from Escom was discussing the siting of new power stations, the relationship between the stacks and the cooling towers and he said that the towers are not situated in the prevailing wind directions expected in winter and summer, but this is not done these days. If we drive in the north eastern Transvaal we suddenly find that the sun is not as bright as it was and this is caused by the amount of suspended air pollution. If we look at the plume from the power stations and from Sasol we are highly disgusted at what some people are doing to our country. I think that ESCOM has accepted that it must do something about these terrible emissions, then we are going to reduce the amount of solids emitted from the power stations. If we accept that the electrostatic precipitators that are being used by the authority are not as efficient as at first accepted in terms of the electrostatic resistivity of the dust that is being passed through, we are likely to get to the terrible state that they have in America.

I have spent a number of years in this country making measurements of sorts at a number of industries and while the lady has made a commendable job running around making measurements of acid rain I think in this country what is lacking at times is source monitoring. While it is alright to point a finger at the big boys, I have noted very high level concentrations from other industry as well, and if I lived in the areas concerned I would be very worried about my health. We have gone a long way in this country but we must start measuring at source and so pinpoint where the pollution is coming from.

The first question is the criticism against using a pH of 5,6 as normal rain; how is normal rain defined?

Margaret Böhm – With no background data we do not know what normal rain is and the chemical content of the rain in each situation must be measured to determine what substances are causing the acidity.

The second question relates to the collection equipment used; this is critical. Are the types of equipment standardised?

Margaret Böhm – The equipment that I showed you is by far the most popular equipment. As to the technique that we are using, is that used by James Gallaway. The University of Virginia is by far the leading authority on chemical composition and on monitoring. Their technique is that they give their site operates 24 hours to collect a sample. Escom has five sites in the Eastern Transvaal and we have a group of people capable of measuring the sample of pH and of collecting it within the 24 hour limit. However we have shown that 24 hours is too long it must be done immediately. This applies particularly to rural air where a lot more organics are present, so what Escom is working on at the moment is an automated system from sample collection to pH measurement to sample storage.

Mr. Wells – (Rand Mines). I would like to ask Dr. Wells if he has measured anything other than sulphate of SO₂ around the burning coal dumps. Has he measured for instance H₂S? No, because of instrumentation problems.