ACIDIC MINE DRAINAGE IN THE REPUBLIC OF SOUTH AFRICA

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Abstract

A brief review is given of the acidic mine drainage situation in the Republic of South Africa, including the sources of pollution, its magnitude and its impact on the natural environment and on the water balance. This is followed by a detailed account of the regulatory measures adopted by both the mining and central governmental authorities to combat the problem arising from the discharge of acidic mine drainage into the natural water courses. Problems encountered by the mines in meeting these measures and regulations are discussed and details are given of the current initiatives to solve these problems.

INTRODUCTION

South Africa is the world's major producer of precious metals and minerals and gem diamonds. There are vast deposits of important industrial minerals such as fluorspar, asbestos, limestone and vermiculite. The country has the world's largest resources of manganese, chromium and vanadium ores, high-grade reserves of iron ore and significant deposits of niobium, tantalum, tungsten and molybdenum. With the possible exception of the Soviet Union, South Africa is probably the most self-sufficient mineral producer in the world. In 1974, South Africa produced 69 per cent of the world's total production of platinum, 30 per cent of the palladium, more than 50 per cent of the vanadium,27 per cent of the chromium and 21 per cent of the manganese. South Africa is also, of course, the world's major producer of gold and has substantial reserves of coal.

In the mining of each of these mineral resources a pollution problem may be created in one way or another with its attendant adverse effects on the available water supply sources.

The mining of gold and coal currently accounts for approximately 90 per cent of the total tonnage mined in the Republic of South Africa and, therefore, the emphasis in this paper will be on acidic drainage arising from the mining of these two mineral resources.

The pollution of surface waters by the acidic drainage of gold and coal mines is a problem which always arises wherever gold and coal mining are undertaken. Pollution from this source adversely affects the aesthetic appearance of streams and rivers. It destroys living organisms that inhabit them, and hence renders them incapable of exerting their self-purifying powers upon polluting organic substances that may enter the water.

Mineral build-up caused by acidic mine drainage presents a formidable problem in South Africa, particularly in view of the fact that it imposes a severe restriction on the beneficial use of water. The effects of this are compounded by the fact that the majority of the gold and coal mines are located in the most highly industrialised and, therefore, the most intensely populated areas in the country where the demands on the fresh water supplies for domestic and industrial use are the highest. The discharge of acidic mine drainage, whether from underground workings or as seepage from slimes and waste dumps into the natural drainage system in these areas, has a profound effect on the critical balance between demand and supply. It is, therefore, advisable to consider the acidic mine drainage problem in the context of the critical balance existing between the present and future demands for and the availability of water.

WATER BALANCE

Approximately 8,6 per cent - on average 52,5 milliard m^3 per year - of South Africa's rainfall reaches the rivers. It is envisaged that, with the improved planning currently being applied (see Table 1), it would be possible to utilise advantageously approximately 60 per cent of the mean annual run-off to yield - together with groundwater resources - a reasonably assured supply of 31,5 milliard m^3 per year. This represents the credit side in respect of distributable water.

TABLE 1. Methods for increasing the assured yield of water in South Africa

Method	Increase (milliard m^3 per annum)
Improving the exploitation of groundwater sources	1,2
Desalination of sea-water (coastal areas only)	0,5
Coupling of river systems	2,3
TOTAL	4,0

On the debit side of the water balance, the total water requirements by the year 2000 will be approximately as follows:

A greater portion of the population will be concentrated in towns and cities - approximately 80 per cent as against the current 48 per cent. The expected water requirements of cities, towns, industries, mining and power generation are 16,7 milliard m^3 per year. The demand for agriculture, mainly irrigation farming, is estimated at 12,8 milliard m^3 per year.

The total annual demand for distributable water in all consumer sectors will thus be 29,5 milliard m^3, i.e. only 2,0 milliard m^3 less than the total estimated distributable water of 31,5 milliard m^3 - 2,0 milliard m^3 being less than two years' increment at the current rate of growth in water consumption. Measures could be applied, however, to reduce water demand, and the following estimates are based on available information :

(i)	Savings through improved utilization of irrigation water	1,5 milliard m^3 p.a.
(ii)	Savings through water reclamation and reuse	7,2 milliard m^3 p.a.
	Total reduction in demand	8,7 milliard m^3 p.a.

From the foregoing, it is clear that the measures envisaged will, in fact, assure a water credit of 10,7 milliard m^3 per year by the end of this century; however, this will be eliminated within the following ten years by increased consumption.

It is also clear that South Africa is rapidly approaching the crisis point where available water resources will no longer be able to meet the demand. In addition, it should be realised that agricultural, urban and industrial development will place increasing pressures on the quality of available water - thereby threatening the usability of these supplies. This major challenge can only be met by careful planning and intensified research. In this effort, effluents resulting from mining activities should also receive the necessary attention.

REGULATORY MEASURES AND STANDARDS

It is the aim of the Water Act of 1956 to protect our limited water resources from pollution. In terms of Section 21 of the Act Act No. 54, specifications have been promulgated to which any effluent resulting from the use of water for industrial purposes shall conform (see Table 2).

TABLE 2. Water Act No. 54, 1956, General Standards (1). Maximum permissible concentrations (mg/l, except where otherwise stated).

pH (value)	5,5 - 9,5
Colour, odour, taste	absent
Dissolved Oxygen	min. 75% saturation
Faecal coli	nil per 100 ml
Temperature	max 35°C
Chemical Oxygen Demand (COD)	75
Oxygen Absorbed (OA)	10
Total Dissolved Solids (TDS)	not exceeding 500 above intake
Suspended Solids (SS)	25
Sodium (as Na)	not more than 50 above intake
Soap, oil, grease	2,5
Residual chlorine (as Cl)	0,1
Free and saline ammonia (as N)	10,0
Arsenic (as As)	0,5
Boron (as B)	1,0
Hexavalent chromium (as Cr)	0,05
Total chromium (as Cr)	0,5
Copper (as Cu)	1,0
Phenols	0,1
Lead (as Pb)	1,0
Cyanides (as CN)	0,5
Sulphides (as S)	1,0
Fluoride (as F)	1,0
Zinc (as Zn)	5,0

Effluents resulting from water used for processing in mining activities must also comply with these standards. The standards, however, do not apply to underground water pumped from mines or run-off from mine dumps. In the case of these waters the regulations, promulgated in February this year (1976) pertaining to measures aimed at the prevention of water pollution resulting from the operation of mines and works (2), do apply. The full text of these regulations appears in Annexure 1 (attached).

PROBLEMS ENCOUNTERED

As has been said, acidic mine drainage from working and abandoned gold, coal and other mines constitutes a most serious pollution problem. Water pumped out from stoped-out underground areas and run-off from mine dumps owing to their high content of dissolved solids, suspended solids and iron, their low pH value and their possible toxicity, can render the water in the receiving water bodies unfit for many applications, unless costly treatment is applied. Their influence on the quality of surface waters is felt by many industries, involving higher costs for water treatment to meet the quality demand for their boiler and process waters.

Mining plays an important role in the Republic's economy, contributing about 12½ per cent of the total gross domestic product and about 59 per cent of the value of total exports. Compared with this, mining as a whole uses little water, only about 4,2 per cent of the total water utilised as shown in Table 3 (3).

TABLE 3. Comparison of the usage of water by the mining industry in relation to the total usage in the Republic of South Africa, 1960 (in morgen feet/year)

	Surface water	Groundwater	Surface and ground	%
Total	3 178 700	426 000	3 604 700	100
mining	54 200	97 000	151 200	4,2

1 morgen foot = 575 000 gallons = 2 600 m^3

Although the mines only use 4,2 per cent of the total amount of water used in the Republic as a whole, the pollution loads carried in mine effluents can impose limitations on the usefulness of the fresh water resources. A typical example is the effect of the acidic mine drainage from the gold fields of the Witwatersrand on the quality of the water in the Vaal-Barrage system.

Table 4 and Fig. 1 show the good quality of the water ex Vaal Dam, the quality of the polluted tributaries flowing into the Barrage, and the resultant deterioration at the Vaal/Barrage discharge point for 1969.

In a survey into the mineral loads contributed by the Suikerbosch and Klip Rivers into the Vaal Barrage during 1967/68 (2), carried out by the Chamber of Mines, it has been estimated that of the total mineral load of 644 t/d total dissolved solids (TDS) discharged via these two tributaries an average of 440 t/d originated from pumped-out underground mine water. These estimates were based on an average flow of 100 Mℓ/d; (in 1957 when most mines were still active, this flow of pumped-out mine waters averaged 168 Mℓ/d).

TABLE 4. Results of physical and chemical analyses of water samples in the Witwatersrand catchment area in 1969 (4). (Monthly average figures)

	Flow, m^3/s		Conductivity+		Total hardness as mg/ℓ $CaCO_3$		Sulphates mg/ℓ	
Engelbrecht's Drift Weir	5,7	49,6	165	195	62	74	5	15
Zuikerbosch Weir	0,06	3,1	350	2550	84	868	56	618
Klip River Weir	1,1	6,5	950	1430	366	716	210	628
Taaiboschspruit Weir	0,003	0,16	560	1520	143	276	83	218
Rietspruit Weir	0,031	2,28	400	2020	80	676	79	729
Vaal Barrage Discharge	4,90	42,4	235	825	92	294	28	215
Vereeniging Pump Station	3,7	7,0	203	721	78	274	22	225

\+ Conductivity in micromhos/cm; to obtain approximate total dissolved inorganic solids, divide by a factor of 1,5.

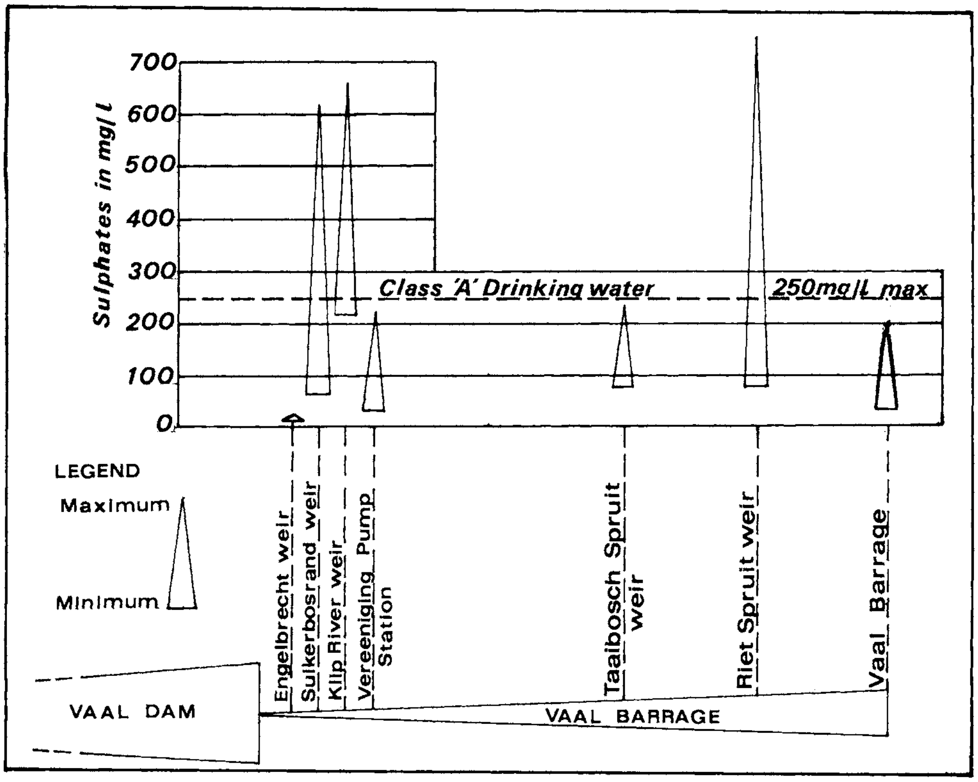

FIG. 1. Sulphate concentration of Vaal Barrage and its tributaries

The total dissolved solids concentration in the Vaal Dam is more or less constant, and is of the order of 100 mg/ℓ. Over a period of almost five years from 1965 to 1969, the monthly maximum for TDS of water abstracted from the Vereeniging pumping station exceeded 500 mg/ℓ during 24 months out of 57 and 700 mg/ℓ during 17 months.

The following table gives estimates of the annual dump run-off and underground mine discharge flows and the dissolved solid loads in these flows for the years 1970, 1980 and 1990. These estimates are based on forecasts for mining and other activities under conditions foreseen at present (5).

TABLE 5. Estimates of the annual run-off and underground mine discharge flows and dissolved solid loads

	1970		1980		1990	
	Flow Mℓ	Load t	Flow Mℓ	Load t	Flow Mℓ	Load t
Dump run-off	3 810	16 800	1 360	6 000	1 360	3 000
Underground waters	33 112	146 000	16 556	73 000	0	0
Totals	36 922	162 800	17 916	79 000	1 360	3 000

It should be noted that the underground water estimates may fluctuate in balance, i.e. the flows may on occasions increase, but on the other hand, the concentrations will probably decrease, thus the loads will remain approximately as estimated.

Effect of mine slimes on purified effluents

To ascertain what the effect of mine slimes in streams had on good quality effluents which were being discharged into them, samples of water were taken at the points of entry and again at points downstream in a silted river-bed (6). The results are tabulated in Table 6 (cases 1 and 2). The significant drop in pH and the tremendous increase in sulphates renders these waters unfit for further use downstream.

TABLE 6. Effect of mine slimes on effluents.

Case 1	Water samples before entering river-bed partially silted with slime	Same water 7 kilometres downstream
Stream flow	85 l/s	28 l/s
pH	6,3	2,4
TDS	395	685
Sulphates in mg/l	82	400
Case 2		
Stream flow	227 l/s	not measured
pH	5,7	1,9
TDS	445	3330
Sulphates in mg/l	124	1160

It has been demonstrated that the effluent run-off of gold and coal mines can be used economically for the irrigation of crops, provided the right conditions are met, including that total dissolved solids are less than about 2000 mg/l, the sodium absorption ratio (which is related to the sodium and the calcium and magnesium concentrations) is low, the pH has been corrected and the iron removed.

The production of acidic mine drainage does not necessarily cease when mining is discontinued. It is, for instance, known that in some mines in Natal water may continue to drain from abandoned workings for years and still contain 4000 - 5000 mg/l TDS, mainly ferrous sulphate. Out-cropping coal seams usually remain a permanent source of pollution (7).

In general, the nature and source of water pollutants created by mining operations, can be summarised as follows (8) :

1. Iron sulphates, derived from the bacterially-assisted oxidation of iron sulphides, are the most generally occurring water pollutants generated by mining operations.

2. The requirement by iron and sulphur oxidising bacteria of an initially acid environment severely limits the rate of sulphide oxidation in many situations. However, when once this requirement has been met, the rate of sulphide oxidation is generally controlled only by the rate at which air becomes available to the oxidation reaction.

3. Partial extraction of an ore body increases the mineral pollution of underground mine waters.

4. Drainage of water from underground mine workings located below surface drainage levels will cease when mining ceases; where mined ore bodies are located above surface drainage levels, mine drainage will persist indefinitely, and pollution loads in such drainage will decline only as the pollutant source decreases.

5. A large potential pollution hazard is created by the deposition of waste solids containing sulphides and soluble minerals on surface dumps and dams.

6. The rate of oxidation and leaching of finely-milled material on slimes dams is very low, provided that the bulk stability and surface stability of the dams are strictly maintained. The fact that the rate of release of pollutants from slimes dams can be held at a relatively low level is particularly significant because in those cases where a large proportion of the tonnage mined is rejected as waste, and the potential pollution hazard is correspondingly great, the ore generally requires to be finely-milled, and the wastes are, therefore, disposed of on slimes dams. Experience has, however, shown that there is a dire need to improve on the design of slimes dams in order to conform to the hydraulic movement of water in the dams and thereby reduce seepage at different levels along the slopes of the dams.

7. A serious pollution hazard is created when iron hydroxides, arising from the neutralization of iron sulphate-containing mine effluents, are precipitated in river-beds.

CURRENT INITIATIVES

From the foregoing, it is clear that the whole problem of pollution by mine effluents has built up progressively as mining activities have expanded over the years and requires the concerted efforts of the mines, local and regional authorities and government bodies in order to find practicable solutions.

1. Prevention

The most effective way to reduce the magnitude of acidic mine drainage is prevention (3). Since the oxidation of pyrite is a function of time and availability of air and water, any approach to reduce pollution requires the control of one of these factors. On active mines, prevention of ingress of water into the workings is the obvious answer. In certain cases this can be achieved by grading the surface area around the mines to ensure good run-off, or by provision of a sufficient numer of adequately sized concrete-lined channels to collect and to divert stormwater.

The mining industry had long sought a method of stabilising tailings dump surfaces to suppress dust, prevent erosion, and reduce the quantity and improve the quality of rainfall run-off from dump sites. After much work by the Chamber of Mines Research Laboratories a satisfactory method of establishing vegetation on tailings dump and dam surfaces was found. In 1964, a unit to undertake this work of vegetation establishment for mine and other clients, was commissioned by the Chamber of Mines.

In establishing vegetation on mine dumps many obstacles have to be overcome. Problems encountered are : deficiency in plant nutrients, fine sand that destroys plant life when wind-blown, acidity which affects germination of plants, and lack of essential microbial population. The sloping sides of waste dumps receive greatly varying amounts of solar radiation; therefore, vegetation suitable for northern and western exposures may not be suitable for southern and eastern slopes. The Chamber of Mines has been investigating all these aspects for years and has found ways to overcome these obstacles. At present, new vegetation is being established on mine dumps at a rate of about 1000 acre/year.

Other measures to prevent run-off and mineral pollution from slimes dams are :

(i) Provision of trenches around the slimes dams to divert stormwater run-off into designed evaporation areas, the so-called 'toe dams'.

(ii) Returning water from the top of the slimes dams after prior settling (9). In 1964, the Department of Water Affairs set up an inspectorate to see that pollution control requirements, where required, were being undertaken. Later the inspectorate was considerably expanded and today has a large section - the Mining and Metallurgical Section of the Pollution Control Division. The first major action taken by the inspectorate was to insist on the recycling of water from slimes (tailing) dams, with the result that surplus top water and rain water are now recycled through the gold-recovery plants.

In a most commendable effort to coordinate existing knowledge and to instigate positive action by the mines themselves, the Chamber of Mines has formulated codes of practice applicable to coal and gold mines for the effective control of acidic mine drainage. The progressive implementation of these codes is already, undoubtedly, resulting in a marked improvement in the mineral quality of mine drainage, and will reduce these problems to manageable proportions.

2. Lime Treatment

Adjusting the pH of acid mine drainage with lime is an old technique (3). For liming, three types of lime can be used, unslaked lime (CaO) with 80-90 per cent calcium (as CaO), hydrated lime ($Ca(OH)_2$) with 60-70 per cent calcium (as CaO), and dolomitic lime ($CaCO_3$ + $MgCO_3$) with 50 per cent calcium (as CaO).

The use of solid lime is not recommended since an impermeable coating of $CaSO_4$ is formed which reduces the efficiency of utilisation. Mixing with water is, therefore, essential. Some mines mix unslaked lime with water in an above-ground installation and pipe the lime slurry into the underground workings for neutralising the acid mine water; other mines, with smaller acid flows, prefer the use of hydrated lime for convenience, as it can be carried in bags for use underground, whereas some coal mines even use dolomitic lime. The choice of neutralising agent is governed by the factors of economics, railage costs, convenience and safety of handling. One disadvantage of using limestone ($CaCO_3$) is the long reaction period needed to treat acid drainage high in ferrous iron, while with hydrated lime $Ca(OH)_2$ the same water is more rapidly neutralised although the sludge produced occupies a larger volume. When lime and limestone are used together, a synergistic effect takes place. The time to oxidise ferrous sulphate is reduced and both sludge settling rate and sludge density are improved.

3. The Bethlehem Process

Another remedial measure to combat effects of mine drainage is the application of the Bethlehem process developed by the Bethlehem Steel Corporation in the United States of America (10). In this process, by recycling the settled solids (after neutralisation, aeration and settling) back to a mixing tank before aerating and adding lime, a very much denser and faster settling sludge could be obtained than by the conventional lime neutralisation plant. All the ferrous iron is oxidised to the ferric state by means of air and the iron is completely precipitated. This process can be applied to any gold or coal mining underground waters, provided that they are acidic and contain iron and sulphate in solution. A colliery investigated the process in detail and in 1974 brought into operation a 14 Ml/d treatment plant. At present a gold mine is constructing a 45 Ml/d plant which is due to come into operation in the latter half of 1976.

4. Establishment of salt water lakes or dams

Mineralised mine and industrial effluents could be harnessed by the establishment of salt water lakes or dams (11)(12)(13). This appears to offer the most practical means of combating the mineralisation of the Vaal Barrage water supply system and thereby ensuring the most efficient utilisation of reclaimable streams and thus contributing to create a positive water balance. There are many uses to which mineralised water could be put, such as cooling water and various process waters for selected industries requiring low quality water. Such lakes and dams can also be exploited to great benefit for recreation which could make a major contribution to the mental health and physical well-being of the people living in the densely populated area of the Witwatersrand. Salt water environments are already exploited in this manner in the Orange Free State as well as on the Witwatersrand.

Such localised impoundment of large volumes of mineralised water may favour large-scale desalination should these processes become economically feasible.

Suitable dam sites for the purpose of creating salt water environments already exist on the Witwatersrand, the Far West Rand and the Orange Free State goldfields area. It has already been experienced that the establishment of such dams cuts down the quantities of effluents to manageable proportions.

5. Pumping of coal with mine effluent

The pumping of coal in a pipeline to the coast by using mine waters is currently being investigated in South Africa. An example of such a possible scheme is the conveying of coal from the Witbank area to Richards Bay. This would require an estimated 90 Ml/d of water which would come partly as underground water from a mine and partly as effluent from a paper industry. This scheme is relevant to the question of desalination in that the water to be used will be saline, and there is always the option of introducing other more saline effluents in future. There is a progressive increase in coal mining activities in many parts of the Republic, and this will be chiefly in open-cast mines.

CONCLUSION

Pollution of surface waters by acidic mine drainage and the resultant detrimental effect on the water balance have always been a vast problem in South Africa and much effort and research have been done to alleviate this threat. The problems encountered with these mine effluents are of such complexity and magnitude that they cannot be solved satisfactorily without the concerted efforts of mines, local, regional and governmental authorities. The Water Research Commission has, therefore, established a Co-ordinating Research and Development Committee to investigate and consider water pollution problems in the mining industry. The whole spectrum of mining activities throughout the Republic is represented in this Committee and it also includes representatives of various Government Departments. This, supported by the codes of practice and the regulations made in terms of the Water Act, together with the provision of impoundments for mineralised water, are considered steps in the right direction - in alleviating the problem in the Republic of South Africa and in ensuring the optimal utilisation of the available water supplies.

REFERENCES

1. Republic of South Africa. Water Act No. 54 of 1956 - Regional Standards for Industrial Effluents. Government Gazette Extraordinary, 5 April 1962.
2. Republic of South Africa. Water Act No. 54 of 1956 - Regulations made in terms of Section 26(c) and (d). Government Gazette No. R. 287, 20 February 1976.
3. G.J. Stander, M.R. Henzen and J.W. Funke, "The disposal of polluted effluents from mining, metallurgical and metal finishing industries, their effects on receiving water and remedial measures", J. S.A. Institute of Mining and Metallurgy, December 1970.
4. Rand Water Board, Nineteenth report on twelve months' examination of samples of water from fourteen sampling points in the Vaal River and Barrage catchment areas (1969).
5. H.T. Clausen, "Dissolved solids load in the Vaal Barrage water system with reference to mine effluent", presented at the Sumposium on dissolved solids loads in the Vaal Barrage system, November 1969.
6. B.A. Thomas, "Planning of gold mines to minimise water pollution problems at closure", presented at Convention : Water for the Future, South Africa, 1970.
7. P.H. Kemp, "Acidic drainage from coal mines with special reference to the Natal coal field", CSIR Special Report No. W.12, Durban, January, 1962.
8. M. Mrost, "The nature and source of water pollutants created by mining operations", presented at Convention : Water for the Future, South Africa, 1970.

9. B.A. Thomas, "The effect of mining industry on public streams", presented at the 1968 Conference of the Institute of Water Pollution Control, East London.
10. E.F. Young and H.E. Steinman, "Coal mine drainage treatment", Proc. 22nd Industrial Waste Conference, Purdue University (1967).
11. H. Olivier, A report on Engineering/Economic criteria in water resource development, II Main Report, April 1968.
12. R.J. Laburn, "The effect of tributary water on Vaal Barrage and the action necessary to ensure that its quality is satisfactory", presented at the 1970 Symposium on dissolved solids loads in the Vaal Barrage system.
13. M.R. Henzen, L.R.J. van Vuuren and G.J. Stander, "Implications of the mineral load in the Vaal Barrage System on Wastewater Reclamation", presented at Symposium of IWPC (Southern African Branch) on dissolved solids loads in the Vaal Barrage water system, Johannesburg, April 1970.

ANNEXURE I

No. R287 20 February 1976

REGULATIONS MADE IN TERMS OF SECTION 26(c) AND (d) OF THE WATER ACT, 1956 (ACT 54 OF 1956)

The Minister of Water Affairs has, by virtuo of the powers vested in him by section 26 of the Water Act, 1956 (Act 54 of 1956), made the following regulations pertaining to measures aimed at the prevention of water pollution resulting from the operation of mines and works :

1. In these regulations, unless the context otherwise indicates, "mine", "works" and "owner" shall have the meaning assigned thereto in the Mines and Works Act, 1956 (Act 27 of 1956), or in the Mines, Works and Minerals Ordinance, 1968 (Ordinance 20 of 1968)(SWA), as the case may be;

   "Act" means the Water Act, 1956 (Act 54 of 1956); and any other expression to which a meaning has been assigned in the Act bears, where used in these regulations, the same meaning.

2.1 Any person who is in control of the operation of a mine or works on the date of promulgation of these regulations shall, within three months of the said date, furnish the Secretary in writing with the following information, and any person who intends establishing a mine or works shall furnish the Secretary with the following information in writing prior to the proposed establishment of such mine or works :

   (i) The name and address of the owner of the mine or works;
   (ii) the name, address and situation of the mine or works together with a plan to scale of the relevant property showing the co-ordinates of the boundary beacons; and
   (iii) such further information as the Secretary may deem necessary.

2.2 The owner of a mine works shall notify the Secretary in writing within 14 days of -

   (i) the appointment of a manager in terms of the regulations made under section 12 of the Mines and Works Act, 1956 (Act 27 of 1956), together with a copy of the letter of appointment;
   (ii) any change in the ownership of a mine or works or any change in the name, address or situation of a mine or works; and
   (iii) any temporary or permanent cessation of the operation of a mine or works, or the resumption of such operation.

3.1 Whenever any manager or employee of any mine or works does or omits to do any act which it would be an offence under these regulations for the owner of the mine or works to do or omit to do, then, unless it is proved that -

   (i) in doing or omitting to do that act the manager or employee was acting without the connivance or permission of the owner of the mine or works; and
   (ii) all reasonable steps were taken by the owner of the mine or works to prevent any act or omission of the kind in question; and
   (iii) it was not under any condition or in any circumstance within the scope of the authority or in the course of employment of the manager or employee to do or to omit to do an act, whether lawful or unlawful, of the character of the act or omission charged;

   the owner of the mine or works shall himself be presumed to have done or omitted to do that and be liable to be convicted and sentenced in respect thereof; and the fact that the owner issued instructions forbidding any act or omission of the kind in question shall not, of itself, be sufficient proof that he took all reasonable steps to prevent the act or omission.

3.2 Whenever any manager or employee of a mine or works does or omits to do an act which it would be an offence under these regulations for the owner of a mine or works to do or omit to do, such manager or employee shall be liable to be convicted and sentenced in respect thereof as if he were the owner.

4. The owner of a mine or works shall provide the manager with the means and afford him every facility which is required to enable the manager to comply with the provisions of these regulations.

5.1 The manager of a mine or works shall cause a plan depicting all works constructed for the control of water on the surface of a mine or works and showing clearly the following details to be kept at the mine or works or such other place as the Secretary may approve in writing:

(i) A subject heading which shall consist of the name of the mine or works and a descriptive name for the plan;
(ii) the successive signatures of all surveyors against the relevant dates as provided for in regulation 5.2;
(iii) the boundaries of the property on which the mine or works is situated;
(iv) the survey system and the coordinates or origin used;
(v) a North point;
(vi) an accurately drawn scale, the proportions of which shall be indicated in metres;
(vii) coordinate lines indicated by fine blue lines not more than 200 millimetres apart with the numerical values written in blue ink at both ends of the lines;
(viii) surface contours;
(ix) natural water courses, reservoirs, vleis, plans and dams;
(x) public roads, railways, residential buildings, offices and other works;
(xi) sewage purification plants and all dams, canals and pipelines for the collection and transport of sewage effluent;
(xii) pumping stations and pipelines;
(xiii) storm-water drains and drains for polluted water;
(xiv) evaporation dams for polluted effluent, protection works, embankments, cut-off drains and diversion channels;
(xv) mineral, tailings and waste-rock dumps and slimes dams, with the proposed annual extensions for the following five years;
(xvi) outlines of open-cut workings and underground worked-out areas; and
(xvii) any additional information which may be required by the Secretary from time to time.

5.2 The plan shall on completion and on all occasions on which it is brought up to date, which may not be more than 12 months apart, be signed and dated by a certificated mine surveyor, appointed in writing for this purpose by the manager of the mine or works.

5.3 A copy of the plan, brought up to date as provided for in regulation 5.2, shall from time to time be submitted to the Secretary on request.

6.1 The manager of a mine or works shall, unless otherwise authorised in writing by the Secretary, on the conditions the Secretary considers necessary to prevent the pollution of any water, cause effective measures to be taken to prevent effluent, including water pumped from underground or which flows naturally from a mine or works, to flow or seep beyond the boundaries of the property on which the mine or works is situated.

6.2 The provisions of regulation 6.1 shall not apply to piped sewage leading to municipal sewage purification plants.

7. The manager of a mine or works shall make adequate provision to the satisfaction of the Secretary to prevent as far as is reasonably practicable, run-off from eroding slimes dams and mineral, tailings and waste-rock dumps due to rain.

8. The manager of a mine or works shall make adequate provision to ensure that all run-off due to rainfall on a property on which a mine or works is situated, is controlled in such a manner by a system of storm-water drains that it flows clear of slimes dams, mineral, tailings and waste-rock dumps and other sources of pollution. Provision shall be made for the maximum precipitation to be expected over a period of 24 hours with a frequency of once in one hundred years. A freeboard of at least 0,5 metre shall be provided throughout the system above the expected maximum water level. Regional rainfall figures shall be based on information obtainable from the Secretary.

9. The manager of a mine or works shall cause all waterways on a property on which a mine or works is situated to be fenced in or otherwise protected to prevent as far as is reasonably possible the pollution of any water in such waterways through any act or omission on the part of any employee of the mine or works.

10. The manager of a mine or works shall, unless otherwise authorised in writing by the Secretary and on the conditions which he considers necessary, take effective measures to prevent any extraneous liquid or other material from entering any evaporation dam, storm-water drain or other waterway on a property on which a mine or works is situated.

11.1 The manager of a mine or works shall cause all slimes dams and mineral, tailings and waste-rock dumps to be so designed and constructed or modified that all rainwater precipitated thereon is retained thereon. Barrier dams and evaporation dams shall be provided where necessary to retain any run-off, including material eroded from slimes dams and dumps. The storage capacities of all dumps and dams shall be sufficient to ensure a freeboard of at least 0,5 metre above the expected maximum water level, which shall be based on the average monthly rainfall figures for the catchment area concerned, less the gross mean evaporation in that area, plus the maximum precipitation to be expected over a period of 24 hours with a frequency of once in 100 years, according to information obtainable from the Secretary.

11.2 Rainwater from tailings dumps and the appurtenant barrier dams and water used in any process at a mine or works shall be recycled wherever possible.

11.3 French drains and ditches to catch seepage water and carry it to evaporation dams or to sumps for recycling, shall be constructed at all tailings dumps wherever seepage occurs.

11.4 All sumps and pumping installations, including catchment dams for the recycling of water, shall be of a design and of adequate capacity to prevent the uncontrolled release of water at any time.

12. The manager of a mine or works shall ensure that any mineral, tailings and waste-rock dump and any slimes, barrier or evaporation dam, storm-water drain or other waterway is as far as is practicable located and designed so as to minimise the possibility of damage thereto by subsidence, settlement, shock and cracking due to past, present or future operations at the mine or works.

13. The manager of a mine or works shall, without causing erosion of the soil, cause all dams, storm-water drains and other waterways to be kept free at all times of plant life and other waterways to be kept free at all times of plant life and other material which may decrease the effectiveness thereof or impede the flow of water.

14. The best practicable means, as determined by the Secretary after consultation with the Government Mining Engineer, shall as soon as possible be implemented by the manager of a mine or works, to prevent erosion of material from the sides of tailings dumps and slimes dams. For the purpose of this regulation the expression "best practicable means" bears mutatis mutandis the same meaning as the meaning assigned thereto in the Atmospheric Pollution Act, 1965 (Act 45 of 1965).

15. The manager of a mine or works shall cause seepage from outcrops, or sub-outcrops occurring on a property on which a mine or works is situated and which does not conform to the standard prescribed in terms of section 21(1)(a) of the Act, to be collected in evaporation dams of sufficient capacity.

16.1 Except with the approval in writing of the Secretary the manager of a mine or works shall not allow any mineral, tailings or waste-rock dump, slimes dam, evaporation dam or any other dam or furrow containing polluted water to be sited near any spring or less than 45 metres, measured along the ground surface, removed from the line indicating the maximum level likely to be reached on an average every fifty years by flood-waters in any river or other watercourse, or any deposition to be made at a site where pollution of water in a watercourse can occur during flood periods.

16.2 The manager of a mine or works shall not allow any mineral, tailings or waste-rock dump, slimes dam or evaporation dam to be sited on water-logged ground or on ground liable to become water-logged, unstable or cracked, or on ground where the slope could occasion a landslide.

17.1 Any person lawfully diverting any water from its course in any drainage area shall make adequate provision for the unimpeded flow on the surface of the ground of water thus diverted, without causing erosion of the soil.

17.2 The holder of any surface right granted in terms of any law relating to mining or prospecting for minerals, shall construct effective diversion drains, of a design that will limit the maintenance thereof to a minimum, to prevent any surface water from entering any mine workings.

17.3 Where surface water is flowing into any mine workings through cracked or fissured ground, sinkholes, outcrop excavations or any other opening, the Secretary may after consultation with the Government Mining Engineer require in writing that the manager of the mine shall cause such places of ingress to be sealed off, or that such entry of water be otherwise prevented.

18.1 The manager of a mine or works shall cause all domestic effluent, including wash-water, which cannot be treated in a municipal sewage purification plant, to be treated in a sewage purification plant capable of producing an effluent conforming to the standard prescribed in terms of section 21(1)(a) of the Act and located at the mine or works or such other place as the Secretary may approve in writing.

18.2 Subject to written approval having been first obtained from the Secretary for Health for the Republic or from the Director of Health Services for South West Africa, as the case may be, and subject to the provisions of section 21(5) of the Act, the manager of a mine or works may allow effluent from a sewage purification plant at a mine or works to be used for irrigation, mining or mineral treatment purposes: Provided that in the case of irrigation the annual application shall not exceed such application as the Secretary may determine in writing.

18.3 The manager of a mine or works shall obtain prior written approval from the Secretary for Health of the Republic or from the Director of Health Services of South West Africa, as the case may be, as to the manner of deposition, utilisation or disposal of sludge from a sewage purification plant at such mine or works.

19.1 The manager of a mine or works shall cause control analyses and determinations of flow rates of subterranean water pumped to the surface and of any effluent to be carried out at such mine or works as determined by the Secretary from time to time by notice in the Gazette. The analyses shall be made in accordance with the methods of testing which may be prescribed in terms of Government Notice R.3208 of 29 August 1969, as amended from time to time: Provided that the Secretary may in respect of any particular mine or works require in writing that any additional control analyses which he considers necessary be carried out.

19.2 Returns of analyses and flow rates of subterranean water pumped to the surface shall be submitted by the manager of a mine or works to the Secretary twice yearly to reflect winter (end of September) and summer (end of March) conditions. In the case of effluents other than sewage effluent, returns of the analyses and flow rates shall be submitted annually as at the end of March. Returns in respect of sewage effluent shall be submitted quarterly.

20. Subject to the approval of the Government Mining Engineer, the Secretary may in writing instruct the manager of a mine to lodge mine spoil and any polluted water other than sewage effluent in the workings of such mine.

21.1 The manager of a mine or works shall cause any part of a property on which a mine or works is situated, whether in operation or not, and which is used or has been used as a depositing site for mineral, tailings or waste-rock dumps or for slimes dams at all times to be kept adequately fenced and he shall not, without the prior approval in writing of the Secretary after consultation with the Government Mining Engineer, allow such property to be used for any other purpose whatsoever.

21.2 Any person removing material from any mineral, tailings or waste-rock dump or from any slimes dam shall be responsible for the repair or re-establishment to the satisfaction of the Secretary of any works for the control of water pollution which existed prior to the said removal of material and which have been damaged or destroyed in the process.

22. Any authorised officer in terms of section 166 of the Act shall be competent to take any sample which he considers necessary in connection with any investigation pertaining to these regulations.

23.1 The manager of a mine or works shall, if required in writing by the Secretary to do so, nominate in writing a number of employees of such mine or works any one of whom shall, after notification to that effect, be present at all occasions on which any sample is taken by an authorised officer and such employee shall on behalf of the manager of such mine or works witness in writing the taking and sealing of any samples.

23.2 The nomination of employees as aforesaid shall be done in such a manner that at least one of them shall at all reasonable times be available to witness the taking and sealing of samples on behalf of the manager of such mine or works.

23.3 If in any prosecution for an offence under these regulations it is necessary, in order to establish the charge against the accused, to prove that the analysis of a sample taken in terms of regulation 22 is a correct analyses of such sample it shall be deemed that any apparatus or instrument which was used to take such sample, or any container in which such sample was placed for despatch to an analyst, was free from any material or contamination which could have had an effect on the result of the analysis until the contrary is proved.

24. Any person who -

(a) contravenes or fails to comply with any provision of these regulations; or

(b) fails to comply with any condition or requirement imposed by the Secretary in terms of regulation 6.1, regulation 10, regulation 17.3 or regulation 20; or

(c) obstructs any officer in the performance of his duties;

shall be guilty of an offence and liable on conviction to the penalties prescribed by section 170(3) of the Act.

Discussion by D.V. Ellis, Canada

There has been very little said about socio-economic as opposed to environmental considerations in water quality management and yet interest in these concerns has been a pronounced feature of changing attitudes on the part of management over the past few years. The problems range from large scale in terms of the international impact of pollution problems in the Rhine to relatively minor problems, the sort of things that arise with Welshmen in the United Kingdom or native people in Canada, South Africa, Australia and the United States of America. Surely more concern will be given to these considerations during the next five or ten years or so.

Reply by L.B. Wood, United Kingdom

In the United Kingdom, socio-economic problems, like all of our present problems, tend to relate to payments, and one of the principal of these is the difference in water charges between different Authorities. In particular, the Welshmen referred to have less in the way of amenities such as mains water and sewerage systems, and yet pay a comparatively higher water rate because of the cost of services to the sparsely distributed population. Consideration has been given to the equalisation of charges among Water Authorities (Daniel Report - 1975) and the dialogue is continuing. If, as has been suggested, a National Water Authority is set up to oversee and coordinate certain functions of the present Water Authorities, this is a matter that they are likely to pursue.

Discussion by K.R. Imhoff, Federal Republic of Germany

I have a few remarks concerning the protection of groundwater and surface water.

Firstly, we have a new discharge law in the Federal Republic which will become effective in 1981 and which says that according to the given pollution everybody has to pay, private people, communities and industry. The charge will be increased from at first 12 DM per capita per year for untreated wastewater to finally 40 DM. The politicians have in mind to give even a greater incentive for water pollution control.

Secondly, in addition to wastewater treatment in densely populated areas, water quality control has become a very important influence to river water quality and the quality of recharged groundwater. Perhaps Mr. Schmidt could make some additional remarks in this direction.

Thirdly, in-stream aeration has been applied in many cases, also in reservoirs. Mr. Higgins mentioned this. A special technique has been developed to not destroy stratification by aerating only the hypolimnion of reservoirs.

Reply by L.B. Wood, United Kingdom

With regard to the proposed legislation in the Federal Republic of Germany, whereby all polluters will be required to pay for the pollution they cause, the Third Report of the Royal Commission on Environmental Pollution in 1972 in the United Kingdom made similar conclusions but suggested that although a polluter should pay for biodegradable pollutants such as B.O.D. and ammonia, persistent pollutants such as toxic metals (cadmiun, mercury etc.) and persistent organic substances must be removed.

Reply by W.D. Schmidt, Federal Republic of Germany

The building of roads, houses and the establishment of new industries require continuously new areas of land. These requirements amount yearly to about 400 km^2 in our country. These building activities mean that wide portions of our surface are clogged, and become inaccessible to the percolation of rainfall water.

During the exploitation of ground resources, mainly during the winning of sand and gravel, ground water is exposed. The annually exposed ground water area comes to 10 km^2. During this process, the evaporation of surface water has negative effects and reduces the amount of ground water.

Last not least, a considerable percentage of ground water is withdrawn from the underground by the lowering of the ground water level in the course of large building projects and this ground water is directly taken to the surface. This quantity amounts, for instance in the extensive brown coal mining open-cast pits near Cologne, to 1,200 million m^3 per annum.

The reduction of the useful quantity of ground water can be avoided only with difficulties and sometimes not at all, as for instance in the Rhenish brown coal mining industry. However, it is now aimed by legal measures at securing the present quantities of ground water. For instance, priorities are given in the plans of the Land Government for Regional Development to the utilization of ground water.

Discussion by K.C. Zijlstra, Netherlands

Could I get some information from the lecture of Mr. Wood on what to do in river basins? You have your water quality objectives, and starting from that you set water quality standards so as to comply with the objectives. In a catchment area therefore you will have to draw up a balance in order to check whether or not conflicts occur between objectives and the water quality to be expected. I believe these three things, water quality objectives, water quality standards and effluent standards in relation to the water quantity, would be the right elements to come to the right strategy to purify water quality in a catchment area. May I have some more information on this relationship in England?

Discussion by W.S. Wakelin, New Zealand

Can I ask Mr. Wood briefly how the river classifications standards in the United Kingdom have been changed? I think that he implied that the standards have been altered or reclassified just very recently. On what basis was this done? What was wrong with the previous standards and in what direction have these new standards gone?

Reply by L.B. Wood, United Kingdom

Prior to the formation of the Water Authorities the various parts of the water cycle were controlled by different authorities. River authorities were responsible for setting standards for effluents and sewage disposal authorities for the operation of sewage treatment works. A publication of the Ministry of Housing and Local Government in 1966 recommended that the Royal Commission standard of 30/20 should be adopted as the norm. The river authority was required to justify more stringent standards and the sewage disposal authority any less stringent standards. These standards clearly could not be relied upon to ensure that at all times the watercourse to which they discharged would be of satisfactory quality to meet the uses required of it.

Moreover the Control of Pollution Act, to which I referred, will, when fully implemented, give the public for the first time the right to prosecute the Water Authority if its effluents are unsatisfactory even on one occasion only. At the same time the Authority is required to keep records of analytical data to be available for inspection by the public. Under previous legislation prosecution could be brought only by River Authorities or with the approval of the Attorney-General. River Authorities are reasonable and appreciate that even with the best management, works could fail to achieve standards at times due to plant failure, bad weather, etc. The public are not so aware of the difficulties and may bring pressure to bear to improve the quality of an insignificant stream with finances required for more urgent purposes such as water supply or first time sewerage where there exists a health risk.

For these reasons an attempt has been made to revise the whole system of setting standards. Firstly, as can be seen in Table 1, an attempt was made to reclassify all the rivers by a procedure which was initiated in Thames Water Authority and which is now to be adopted by all water authorities throughout the United Kingdom. Rivers are assigned to classes based upon the use to which they are to be put. Basically the highest Class (1A) is of rivers which support good game fisheries and which are used for potable supply. The next class (1B) is not quite so good; such rivers would support good coarse fisheries and could be used for potable supply. The classification then proceeds through to Class X which represents an insignificant watercourse with little amenity value but which requires to be kept from becoming a nuisance. The table shows class limiting criteria as quality parameters which must be met for 95% of the time. Where a river is required for uses which put it into a class for which it does not meet the quality parameters and the remedial work necessary to bring it to the required quality does not rank highly in the Authority's list of priorities, it is designated as requiring upgrading. For example such a river required to be in Class 1B but at present of quality criteria meeting only Class 2 is designated 2/U1B and will be regarded as 2 until sufficient finance is available to restore it to 1B.

TABLE 1.

Suggested Classification of River Quality.

River Class	*Current potential uses*	*Quality criteria*		*Remarks*
		Class limiting criteria *(95 percentile)*	**Average criteria**	
1A	(i) Water of very high quality suitable for potable supply abstraction and for all other abstractions (ii) Game and high-class coarse fisheries (iii) High amenity value	(i) D.O. greater than 80% saturation (ii) B. O. D. not greater than 3 mg/l (iii) Ammonia not greater than 0.4 mg/l (iv) Within other E. E. C. Category A.2 requirements (v) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available)	B.O.D. not greater than 1.5 mg/l	Physical evidence of pollution should be absent
1B	Water of less high quality than Class 1A but usuable for substantially the same purposes.	(i) D.O. greater than 60% saturation. (ii) B.O.D. not greater than 4 mg/l (iii) Ammonia not greater than 0.9 mg/l (iv) Within other E. E. C. Category A2 requirements (v) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available)	(i) B. O. D. not greater than 2 mg/l (ii) Ammonia not greater than 0.5 mg/l	(i) Physical evidence of pollution should be absent (ii) Waters of high quality which cannot be placed in Class 1A because of high proportion of high quality effluent present or because of the effect of physical factors such as canalisation, low gradient or eutrophication (iii) Class 1A and Class 1B are essentially the Class 1 of the River Pollution Survey
2	(i) Waters suitable for potable supply after advanced treatment (ii) Supporting reasonable good coarse fisheries. (iii) Moderate amenity value.	(i) D.O. greater than 40% staturation (ii) B. O. D. not greater than 8.5 mg/l (iii) Ammonia not greater than 2.5 mg/l (iv) Within other E. E. C. Category A3 requirements (v) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available)	B.O.D. not greater than 5 mg/l	(i) Similar to class 2 of R. P. S. (ii) Water not showing physical signs of pollution other than humic colouration and a little foaming below weirs
3	Waters which are polluted to an extent that fish are absent or only sporadically present. May be used for low grade industrial abstraction purposes. Considerable potential for further use if cleaned up.	D.O. greater than 10% sat. (daytime) and not likely to go anaerobic. B.O.D. not greater than 17 mg/l*		Similar to Class 3 of R. P. S.
4	Waters which are grossly polluted and are likely to cause nuisance	D.O. less than 10% saturation and likely to be anaerobic at times		Similar to Class 4 of R. P. S.
X	Insignificant watercourses and ditches not usable where objective is simply to prevent nuisance developing	D.O. greater than 10%		

* This may not apply if there is a high degree of re-aeration.

Note. (a) Under extreme weather conditions (e.g. flood, drought, freeze-up), or when dominated by plant growth, or by aquatic plant decay, rivers usually in Classes 1, 2 and 3 may have B. O. Ds. and dissolved oxygen levels, or ammonia content outside the stated levels for those Classes. When this occurs the cause should be stated along with analytical results.

(b) The B. O. D. determinations refer to 5-day carbonaceous B. O. D. (ATU). Ammonia figures are expressed as NH_4.

(c) Each class is valid only if the stream has a biota appropriate to the observed chemical and physical characteristics.

Having reclassified the rivers and established the relevant 95 percentile quality parameters, it is possible by means of mathematical models or reference to past data, to establish standards required of effluents in order that the river quality shall be achieved for 95% of the time.

We shall then proceed to establish a system for assessing priorities for maintenance and upgrading of effluents and the finances available will be spent in the best manner in the interests of ratepayers.

Discussion by C.C. Sanders, Australia

A question to Mr. Schmidt. Have studies been undertaken in Germany or elsewhere in Europe into the surface environmental effects of intensive groundwater usage. Is the natural vegetation dependent on groundwater as it is in parts of Australia? If so what is the effect on the vegetation of heavy groundwater withdrawal and on the fauna dependent on the vegetation as a habitat and also are local wetlands affected?

Reply by W.D. Schmidt, Federal Republic of Germany

The largest influence on vegetation is exercised on the area of the user, the greatest subsidence of the groundwater level occurs in the vicinity of wells where, in most of the cases, the user is the groundowner at the same time. When, in further areas, a change in water levels is feared which could affect badly the vegetation then, at the beginning or before the use, investigations on plant sociology are made. We must see to what extent vegetation is affected. However, there are cases where, in the past, groundwater levels have been lowered over wide areas which led to changes in the vegetation. An example is the correction of the Rhine River between the towns of Freiburg and Mannheim.

Discussion by A.S. Howard, Australia

As a Victorian I think we are most grateful for Mr. Wood's paper. The subject was "Management" and he showed us an organisation and administrative structure in England that functions effectively.

In Victoria those functions which he listed as the responsibility of the Water Authority, are fragmented into several government departments and local authorities and we have utter chaos.

I would like to ask Mr. Schmidt could he make some further remarks on the regulations relating to motor transport of oil. He referred to them in connection with groundwater catchments. Are there similar regulations for surface water catchments?

Reply by W.D. Schmidt, Federal Republic of Germany

There is a restriction in Germany where, in certain threatened areas, oil can only be transported in quantities up to 3 m^3, in order to reduce the danger or the consequences of an accident.

Before pipelines are laid, the optimum route is discussed with the competent Authorities and interested parties. The pipelines for a transport of oil are designed specially such as to prevent leakages. Percolation and leakage indicators, too, must be built-in such as to give immediate alarm. That does not necessarily mean that accidents do not happen at all, but the special design and the indicators contribute to avoid them.

Discussion by T. Farrell, Australia

As someone vitally interested in the problems of mining companies and water quality I would like to ask Dr. Henzen several questions regarding the situation in South Africa. First of all, are the mining companies required to contain all water on the lease including stormwater, and if not, do you specify a frequency of storms beyond which they are not required to contain?

Secondly, do you take into consideration, when looking at streams flowing through the mining leases, the quality of this water before it enters the mining lease?

Thirdly, does your government give any financial assistance to the mining companies for water quality control?

Reply by M.R. Henzen, Republic of South Africa

With regard to the requirements of the Republic of South Africa for the containment of rainwater on mining properties, the mine manager is responsible to make adequate provision to ensure that all run-off due to rainfall on a property on which a mine or works is situated is controlled in such a manner by a system of stormwater drains that it flows clear of slimes dams, mineral tailings, and waste rock dumps, and any other source of pollution. Provision here is also made for the maximum precipitation to be expected over a period of 24 hours with a frequency of once in a hundred years and a freeboard of 0.5 metres shall be provided throughout the system above the expected maximum water level. The regional rainfall figures for determining this shall be based on information supplied by the Secretary of the Department of Water Affairs.

Concerning adjustments to the water quality requirements due to water quality effects of streams flowing through mining property, the Department of Water Affairs has its own water quality monitoring system throughout the country. In cases where mines are located within the catchment of streams originating outside the property of the mine, the Department of Water Affairs will establish stations both above and below such a property. The management of a mine is also required to submit records of the flows of water pumped from underground and also of any other waters on the mining property, which is derived from mining operations, and to submit the records of the analyses to the Department of Water Affairs twice per year. This is done in such a fashion that it would reflect the conditions during the dry and wet seasons in order to distinguish between the effects of surface run-off and the discharge of underground water. Monitoring in this manner is essential since it allows the effective control of the measures adopted by the mines and the unwarranted discharge of underground water from mines which can contain up to 10 000 mg/l of total dissolved solids.

Regarding financial assistance to mines for controlling pollution, I suppose that gold mines are financially in such a strong position that they do not require any assistance. No provision is however, made by the State authorities to assist mines financially for controlling pollution. As indicated earlier on the regulations were formulated to cater for a very wide range of different types of mines in the country. A very thorough study of the coal and gold mine was however undertaken because of the problem of acidic mine drainage, which is a very critical problem in South Africa. The mining companies fully realising their responsibilities have in many instances already implemented the said control measure before the promulgation of the regulations.

Discussion by H. McFie, Australia

Not all mine problems actually turn up in mines. When we build underground power stations we are of course in a mining activity, and on occasions we have in fact encountered pyritic ores or seams with rather disastrous results on some of our structures. Care must be taken otherwise sections of extensive and expensive copper earth mats rapidly disappear in a dripping groundwater of pHs of 2.9 and total solids of 3-4000 mg/l.

The question which is principally for Mr. Schmidt is whether the regulations that he has outlined, cover, or are intended to cover, temporary works such as major construction on rivers. I am speaking specifically of dam building, which of course often requires extensive stripping on the abutments of the dam, the winning or acquiring of materials adjacent to the dam, and inevitably, a good deal of turbidity and other waste materials finish down river. Perhaps you could explain what Continental practice is in this regard.

Reply by W.D. Schmidt, Federal Republic of Germany

In new dams especially dams for drinking water, we are trying to build a lower dam upstream before the main dam, so that it collects the water before it flows into the main reservoir. That is a safety factor and it takes away oil particles before the water reaches the main reservoir.

Reply by M.R. Henzen, Republic of South Africa

Any water abstracted from a river or supplied by a water supply system to a mine for any processing or for construction purposes is subject to the regulations as promulgated under the Water Act of 1961.

Discussion by M.L. Prabhakar, India

I wanted to tell what we have done in India about Water Quality Management. In 1974 we have made an enactment known as the Water (Prevention and Control of Pollution) Act 1974. According to this Act we have set up State Boards for various States In India and there is a Central Board for all the whole of the country which controls the work of the State Boards.

According to this Act each industry has actually to apply to the State Boards to obtain consent. Our experience during the last few years after the enactment is that most of the new industries are quite cooperative and they think that there is nothing doing without complying with the provisions of the Act. But the existing industries are not very cooperative and they try to sidetrack the Act and put off things.

I would like to know of experiences from other countries in dealing with existing industries. During the previous two years we tried the method of persuasion, but recently we felt that this was not working well.

Reply by P.M. Higgins, Canada

Our experience in Canada, and I am sure this applies elsewhere, is that we have no difficulty in requiring new industry to meet environmental control requirements. The same ease of application of requirements cannot be said for existing industry; the problem is much more complex. Certainly in Canada we are finding that we have some successes with existing industry, but nearly every time that we have a significant success with an existing industry, it is at a time when that industry is in the process of expanding or changing process. We in Canada as in India, attempted to use a persuasive approach, a cooperative approach. We find that a persuasive approach works reasonably well as long as you have a fairly reasonable stick to hold over your head in terms of effective control legislation, and there are times when we have to use the stick. I do not think I would like to be responsible for a regulatory program whereby one only had the stick and whereby one did not try and cooperate and work with industry. I think we need both and that is the approach we are taking in Canada.

Discussion by J.W. Lovell, Australia

I would like to ask Mr. Wood how or in what way, are the River Authorities tied to the Planning Authorities in the U.K., that is, what is their inter-relationship?

Reply by L.B. Wood, United Kingdom

The Water Authorities have their own Planning Directorate which is advised by other Directorates (such as Scientific Services, Finance and Operations) and works in liaison with County and Local Authority Planning organisations. The problems are of two kinds: long-term strategies which involve mainly the County Authorities and Regional Directorate of the Water Authority, and those which require more immediate short-term decisions which are usually settled by Local Authorities and Divisional Managers of the Water Authorities.

The former strategies would involve such matters as development of new estates, when it is a statutory requirement that the Water Authority must be consulted in respect of water supply, sewerage and sewage disposal and flood prevention.

The Control of Pollution Act requires the County Authority as (solid) Waste Disposal Authority to make long-term plans for waste disposal which must be devised in consultation with the Water Authority. Sites for such disposal must also be licensed and the approval of the Water Authority sought before licences are granted.

Short-term planning largely involves the Local Authority in submitting plans for new buildings, and extensions thereto, to the Divisions of the Water Authority when any aspect of the Authority's work, such as pollution prevention, is involved.

Discussion by M. Riha, Australia

I would like to ask Mr. Schmidt what action was taken, either legal or remedial, by the authorities in areas where pollution of the groundwater already exists.

Reply by W.D. Schmidt, Republic of Germany

If the groundwater is polluted then it is really too late to help. There are different examples in Germany. The example most worth mentioning was due to a tank storage in the direct neighbourhood of a waterworks - the water became polluted to such an extent that the whole waterworks had to be closed down. As a recent case in the Ruhr District, chemicals have run out from tanks of a wholsesaler and polluted the groundwater. In order to protect a nearby waterworks, it was necessary to pump out the polluted groundwater, to filter it through activated carbon and to discharge it into the next river.

Discussion by S.H. Jenkins, United Kingdom

We heard that in Canada arrangements are made for determining the toxicity of substances that are discharged to watercourses on a regular monitoring basis. It seems to me that in every industrialised country there should be the possibility for manufacturers to consult with Government and regulatory agencies on the possibility of substances that are proposed as commercial products, to be tested for all environmental purposes. In certain countries there are arrangements for tests of this kind to be carried out on a basis of strict confidentiality and I would invite comments from all our speakers as to the success or desirability of having an arrangement of this kind.

Reply by P.M. Higgins, Canada

Part of the regulatory program in Canada is to require new industry to assess the toxicity of effluents and report to Government. We have recognised the problem of new chemicals and new products coming on the market at almost an alarming rate and we now have in Canada a new Environmental Contaminants Act which will require those people producing new chemical products to evaluate those products based upon protocols established by the Government. Because of the very proprietary nature of some products, the program is one that is enacted jointly between government and industry on a confidential basis. It is too early to tell at this stage to what degree we are going to be successful, we look upon this new program as a very large one, a very challenging one. Perhaps two years from now in Stockholm someone from Environment Canada might be able to speak to this meeting on the success of our new Environmental Contaminants Act.

Summary by K.W. Lewis, Australia - Session Chairman

I have drawn about four conclusions and the first is that effective water quality management can only proceed within a framework of comprehensive environmental and economic policy embracing air pollution management and I think Mr. Higgins' comment on the soft water lakes of Canada makes this point particularly. Land management total water resource management - at Regional, State, National and hopefully of course at International level. I think this will become even more important as many nations proceed toward full water development.

Water quality policies must incorporate both short and long term objectives in order to recognise community expectations and at the same time the capacity of the community to pay or to meet the costs of enhancement and/or maintenance of water quality.

Water quality management must be supported by practical legislation to provide for both the general control of water quality and also the specific requirements for any particular resource through area oriented regulations.

The development and implementation of water quality management practices need to be based on more intensive study and research on the problems involved and the strategies available in solving these problems. In this respect I think that conferences and workshops of this nature have an important role in promulgating and sharing our experiences.