WATER RESEARCH COMMISSION PROJECT NO. 201

TREATMENT OF INORGANIC BRINES AND CONCENTRATES

APPENDIX 2

Visit to the AECI Chemicals and Explosives Factory at Modderfontein
27 and 28 July 1987

Pollution Research Group
Department of Chemical Engineering
University of Natal
Durban

October 1990

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1. INTRODUCTION

Two members of the Pollution Research Group visited AECI Chemicals and Explosives Ltd, Modderfontein, on the 27 and 28 July 1987 in order to obtain general background information regarding processing, effluent production and effluent discharge at the factory.

2. GENERAL

The AECI plant at Modderfontein manufactures explosives, chemicals and accessories such as detonators and fuses.

The total factory operations include :-

(i) the central factory area for chemical manufacture.
(ii) the BE/WEX areas for explosive production.
(iii) detonator manufacture area.
(iv) fusing manufacture area.
(v) magazine area for explosive storage.
(vi) a farm for spray disposal of nitrogenous wastes. The crops produced are used to rear sheep and cattle.
(vii) a sewage plant and various industrial effluent associated operations/installations.

The factory site covers 4 000 hectares. Approximately 8 000 people are employed at the site.

The majority of the products manufactured are nitrogen based. Ammonia, produced at the site by burning coal with nitrogen and hydrogen, is the basic building block for processing.

Ammonia is oxidised to nitric acid which, on reaction with ammonia produces ammonium nitrate, one of the major products produced at the factory. It is produced as a solution (93%) or in prilled form. Approximately 20% of the ammonium nitrate is converted into limestone ammonium nitrate for use as a fertiliser and the remaining 80% is used as a base for explosive manufacture.

Nitroglycerine based explosives are also produced at the factory. Nitroglycerine is produced at the site by the reaction of nitric acid and glycerine or glycerol.

Urea, methanol, formaldehyde and products for high velocity explosive manufacture are also manufactured by reacting various combinations of ammonia, coal burning products and/or carbon dioxide.

Batch operations are carried out for the manufacture of various chemicals such as lead nitrate, copper sulphate, sodium bisulphite and aluminium sulphate. Various acid dilutions are also prepared and speciality chemicals such as Inderol, a pharmaceutical product, are manufactured.

3. WATER SOURCES

The factory consumes raw water from three sources :-

(i) Johannesburg purified sewage (Table 1). This is used for applications such as the quenching of hot ash, washing, gas scrubbing and the transfer of slurries.

(ii) Modderfontein purified sewage (Table 2).

(iii) Rand Water Board water (Table 3). 60% of this is used in the cooling systems. Of this fraction 85% is lost as water vapour.

In addition a recycle system within the factory enables further reuse of weak effluent.

TABLE 1 : Typical Analysis of Johannesburg Purified Sewage

	mg/l
NH_4	6
NO_3	50
Cond (μS/cm)	750
Na	86
Cl	60
SO_4	140
TDS	503
Daily consumption	50 Ml

TABLE 2 : Typical Analysis of Modderfontein Purified Sewage

	mg/l
NH_4	20
NO_3	15
Cond (μS/cm)	800
Na	57
Cl	50
SO_4	140
TDS	515
Daily consumption	50 Ml

TABLE 3 : Typical Analysis of Rand Water Board Water

	mg/l
Ca	35
Mg	4,4
Na	14
Cl	10
Cond (μS/cm)	200
TDS	137
SO_4	10
Daily consumption	31 Ml

4. EFFLUENT ARISINGS AND DISCHARGE

All the effluents produced at the factory are segregated into two discharge streams. The weak effluent (1 000 to 1 200 m^3/h) is discharged under permit, together with storm water into the Jukskei River. The strong effluent (20 m^3/h), mainly nitrogenous, is sprayed onto 2 500 hectares of leased and owned land.

The present factory permit for effluent discharge (TDS = 1 650 mg/l) applies to weak effluent disposal only. AECI are aiming to meet the general standards of effluent discharge by 1990. In order to achieve this, the TDS load of the weak effluent must be reduced. Although process modifications may occur, AECI foresees that some form of residual effluent treatment cannot be avoided.

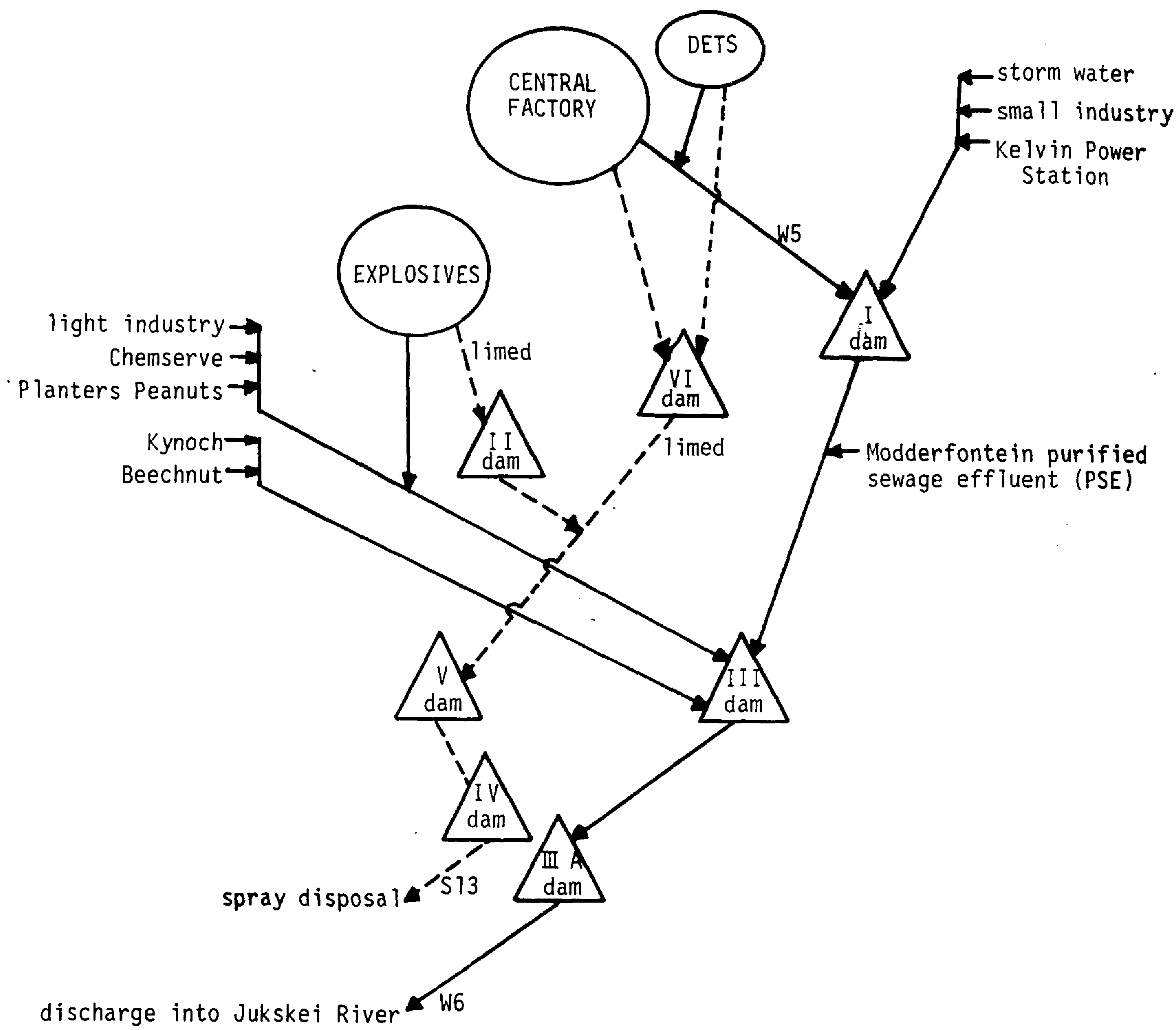
As regards the strong effluent, spray disposal is expensive. Although some tuning is possible, in most cases reducing the arisings at source would involve major capital expenditure. A few exceptions to this include Powergel manufacture.

Figure 1 depicts the effluent system at the factory.

FIGURE 1 : The effluent system at AECI, Modderfontein

——— weak effluents

- - - - strong effluents



Notes : (i) Dam VI is limed.

(ii) Dam IIIA is a bypass dam

(iii) Some of the Modderfontein PSE is used in the central factory as raw water and there is a 30% recycle of weak effluent from Dam III back to the factory.

Of the arisings contributing to the weak effluent the major areas for concern are :-

(i) the contribution, both load and volume, by the stream entering Dam I from the power station. This stream varies in flow from 400 to 800 m^3/h and constitutes up to 60% of the volume of the weak effluent discharge. In addition, it is high in suspended and dissolved solids. The only advantage of this stream is that it is slightly alkaline and contributes to the precpitation of heavy metals, produced during the combustion of coal, at the AECI factory.

(ii) the ion exchange regeneration chemicals from No. 4 ammonia (see section 5). This stream contributes to almost 25% of the AECI factory weak effluent discharge volume (excluding Kelvin power station) and has a TDS loading of 5 to 10 times higher than the final weak effluent.

Table 4 gives the chemical loads discharged in :-

(i) W5, the main weak effluent stream from the central factory and

(ii) W6, the final weak effluent discharge

for the winter of 1986 and the summer of 1986 to 1987.

The chemical loading in the weak effluent streams is generally higher in summer due to the solution of waste chemical deposits over the factory site during the rainy season. Approximately 35 to 54 tons of TDS is discharged daily into the Jukskei River in the form of weak effluent.

The main volume contributor to the strong effluent is the demineralisation water from No. 11 nitric acid plant (10 m^3/h). Various ammonium nitrate discharges from the explosives area constitute the remaining strong effluent.

TABLE 4 : Annual Average of Weak Effluent Chemical Loading

W5 - Central factory discharge (kg/h)

	Winter 1986	Summer 1986-1987
TDS	1 445	2 238
NH_4	46	64
NO_3	69	113
Na	197	293
Cl	163	196
SO_4	530	734

W6 - final weak effluent discharge (kg/h)

	Winter 1986	Summer 1986-1987
TDS	681	1 052
NH_4	26	53
NO_3	29	60
Na	83	156
Cl	37	60
SO_4	291	411

A general recommendation concerning all effluent discharges is that suspended matter and chemical precipitates should be removed from segregated effluent streams before they combine to form the final effluent. In this manner chemicals and salts may be removed from solution before dilution with other streams occurs, and hence possible resolution.

5. NO. 4 AMMONIA PLANT

The No. 4 ammonia plant is the largest consumer of water at the factory. It requires extremely high quality water for the high pressure, high temperature boilers which have a combined evaporative capacity of 400 to 500 m^3/hour.

The boilers operate at seven cycles of concentration. There is a forced blowdown of 60 to 70 m^3/hour on the cooling system for use in ancillary cooling systems, gas scrubbers and for other uses. This blow-down is a large contributor to TDS.

The water to the boilers is deionised in a series of ion exchange columns. The objective of the ion exchange unit is to ensure that a secure source of high quality water is produced to meet constraints downstream.

There are three sets of columns; one in operation, one on standby and one undergoing regeneration. Each set consists of an anion column, a cation column and a mixed bed reactor. At present the columns are operating at full capacity due to the high TDS in the Rand Water Board water. Approximately 250 m^3 of water/hour passes through the ion exchange unit. Of this, 160 m^3/hr is fed to the boilers while the residual is consumed during regeneration of the resin. There is no pretreatment to remove suspended or colloidal contaminants of the raw water feed before ion exchange processing. The water is decarboxylated after cation exchange to remove carbon dioxide and carbonates before anion exchange. The water is then degassed before entering the mixed bed ractor. The water is dosed with ammonia and hydrazine prior to being fed to the boiler.

Resin regeneration cycles commence automatically as the level of a chosen contaminant exceeds a predetermined breakthrough concentration in the eluted water :-

(i) in the cation exchange columns the sodium breakthrough limit is 0,1 ppm. The average regeneration frequency is 6 to 12 hours.

(ii) in the anion exchange columns the silica breakthrough limit is 0,03 ppm. There is also a conductivity limit of 10 μS/cm. The average regeneration frequency is 8 to 16 hours.

(iii) in the mixed bed reactors breakthrough determinants are sodium and silica as in (i) and (ii). The conductivity limit is 1 μS/cm and the average regeneration frequency is 2 to 3 weeks.

Regeneration involves :-

(i) backflushing of the column with water to remove suspended solids from the column.

(ii) preinjection to prevent the formation of air pockets in the resin.

(iii) in the case of cation resin regeneration, a low concentration sulphuric acid wash (2%) for 45 minutes to remove calcium while at the same time inhibiting calcium sulphate precipitation. This, is followed by a polish using 4% sulphuric acid for 1 hour.

(iv) in the case of anion resin regeneration, a 4% sodium hydroxide wash at 35°C.

(v) in the case of the mixed bed reactor, the transfer of resin is to a second vessel for regeneration as in (iii) and (iv).

(vi) a rinse at a flow of 90 and 100 m^3/hour for 110 minutes for the cation and anion columns respectively. In the case of the cation resin rinse, backwash and make-up Rand Water Board water is used. In the case of the anion resin rinse, degasified Rand Water Board water and backwash water is used and recycled after 15 minutes.

Approximately 4 200 kg of 98% sulphuric acid and 2 700 kg of 100% sodium hydroxide are consumed daily for regeneration of the No. 4 ammonia ion exchange unit.

The regeneration streams (160 to 200 m^3/h) contain high levels of sodium sulphate and are the only strong effluent streams discharged with the weak effluent.

AECI have been addressing the problem of pollution loading in these particular streams :-

(i) they are looking at the option of installing a further set of columns in the beginning of the process and using spent regeneration liquors from the existing column to regenerate the new columns. This could reduce their chemical consumption by half.

(ii) various spent streams are being reused e.g. backwashing waters and anion resin rinse water.

(iii) they are investigating the effectiveness of shorter regeneration times.

(iv) they have considered the application of reverse osmosis as a pretreatment to ion exchange to reduce the effluent chemical loadings.

(v) they have considered the application of multistage distillation process prior to ion exchange.

Modifications would be advantageous if the :-

(i) water throughput could be increased.
(ii) regeneration cycle time could be increased.
(iii) chemical demand could be decreased.

All modifications must be carried out while maintaining the same quantity and quality of product water.

Two proposals discussed were :-

(i) the use of reverse osmosis as a barrier between ion exchange and the boilers. This would ensure a high quality water product, with minimum reverse osmosis membrane scaling and a considerable reduction in the frequency of regeneration.

(ii) the development of a treatment process which will recover acid and base regenerants of suitable quality for reuse in the system.

WEX

Powergel is one of the products of the Wet Explosives factory (WEX). The problems encountered in production and waste disposal are similar to those encountered at Zomerveld. The recommendations concerning resource conservation and effluent treatment and prevention for this type of production process have been discussed with AECI personnel and have been presented in a separate series of reports.