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**JAWAHARLAL NEHRU ALUMINIUM RESEARCH DEVELOPMENT AND
DESIGN CENTRE**

DP/IND/88/015/11-52

INDIA

Report of the Consultant in Alumina Production

Prepared for the Government of India
by the United Nations Industrial Development Organisation,
acting as executing agency for the United Nations Development Programme

Prepared by Dr. P.J. Cresswell

Consultant

Backstopping officer: Dr. T. Grof

United Nations Industrial Development Organisation
Vienna

EXPLANATORY NOTES

Currency: US\$1.00 = Indian Rupees 30 (approx.)

ABBREVIATIONS: ORGANISATIONS

BALCO Bharat Aluminium Company

HINDALCO Hindustan Aluminium Company

INDAL Indian Aluminium Company

JNARDDC Jawaharlal Nehru Aluminium Research Development and Design Centre

NALCO National Aluminium Company

QAL Queensland Alumina Limited (Gladstone, Australia)

ABBREVIATIONS: TECHNICAL

CAL Aluminate liquor (feed to precipitation)

CGM Crystal growth modifier

Hydrate Aluminium tri-hydroxide

MR Molar ratio $\text{Na}_2\text{O} / \text{Al}_2\text{O}_3$

SOF Settler over-flow

ABSTRACT

PROJECT TITLE: JAWAHARLAL NEHRU ALUMINIUM RESEARCH
DEVELOPMENT AND DESIGN CENTRE

NUMBER: DP/IND.88/015/11-52

MISSION: Consultant in alumina production, especially in the behaviour
and treatment of organics in the Bayer process

OBJECTIVES:

1. To review the "organic impurities" situation in the Indian alumina industry and make recommendations for improvements.
2. To provide consulting and training services in the field of organic impurities in the Bayer process.

DURATION: Three months

CONCLUSIONS:

The levels of organic impurities in Indian bauxites and alumina refineries are in the low to medium range, by world standards. Plants with older technology may nonetheless have difficulty coping with these levels.

The industry has insufficient knowledge of the nature of the organic impurities, their effects on the process and of how these problems have been tackled elsewhere in the world.

Inadequate analytical facilities are also a bar to effective identification of problems and solutions.

JNARDDC must establish good facilities and develop its skills in the field of organic impurities and of precipitation technology.

The companies should support this development by entering into collaborative projects.

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INTRODUCTION

Background to the project

The establishment of the JNARDDC is a joint project of the Government of India and UNIDO to assist the development of the Indian aluminium industry. Part of the UNIDO contribution to the project is the provision of foreign 'experts' to provide consulting and training in specialist fields. One such field identified for attention is "The Behaviour and Treatment of Organics in the Bayer Process". The Job Description for the position is reproduced in Annex I.

The position was taken up by Dr. P.J. Cresswell for three months, commencing 11 January 1993.

This report was prepared by Dr. P.J. Cresswell.

Objectives

The initial objectives are outlined in Annex 1. The detailed programme arrived at after discussion with the Technical Adviser at JNARDDC is attached as Annex 2. The key points are:

1. To review the "organic impurities" situation in the Indian alumina industry and make recommendations for improvements.
2. To provide consulting and training services in the field of organic impurities in the Bayer process.
3. To assist in the upgrading of the existing process mass balance model to allow variable temperature profiles in the precipitation area.

This includes some work on process modelling because of the author's experience in this field and its relevance to the project and to the work of the Centre.

Attainment of objectives

All of the main objectives of the project were attained. Detailed analysis of the situation in the plants was limited by lack of suitable data, though this did not prevent the formulation of general recommendations.

I. ACTIVITIES

- Visits to operations: BALCO, HINDALCO, NALCO
- Discussions with industry representatives at JNARDDC: above companies and INDAL
- Assessment of the situation in the industry
- Preparation of a case study for the BALCO refinery
- One day workshop at JNARDDC with staff and industry representatives to discuss the findings of the mission
- Preparation of review report on 'Analytical Methods for Organic Impurities'
- Training of JNARDDC staff through informal consulting and discussions
- Provision of technical literature to the centre: about 150 items were provided, including papers, patents and a 'Dialog' literature search.
- Assistance with process modelling, particularly in the area of precipitation

II. OUTLINE OF THE INDUSTRY

There are currently five companies active in alumina production in India:

Bharat Aluminium Co. (BALCO)

Ownership: Govt. of India

Operation: Korba (Madhya Pradesh) - 200,000 t/y

Hindustan Aluminium Co. (HINDALCO)

Ownership: Birla Group & other private investors

Operation: Renukoot (Uttar Pradesh) - 300,000 t/y

Indian Aluminium Co. (INDAL)

Ownership: Alcan & other private investors

Operations: Belgaum (Karnataka) - 200,000 t/y

Muri (Bihar) - 75,000 t/y

Madras Aluminium Co. (MALCO)

Ownership: Private investors (foreign & local)

Operation: Mettur (Tamil Nadu) - 60,000 t/y (currently not in operation)

National Aluminium Co. (NALCO)

Ownership: Govt. of India; some privatisation is under way.

Operation: Damanjodi (Orissa) - 300,000 t/y

With the exception of Nalco, most of the alumina produced is consumed by the local market. There are plans for major expansion of the industry over the next five years, focussing on the export trade.

III. ORGANICS IN THE BAYER PROCESS

A. Introduction

All bauxites from tropical deposits contain carbonaceous material, derived from soil or vegetation, which becomes incorporated in the minerals during the geological formation process. When the bauxite is dissolved in caustic soda, in the first 'digestion' stage of the Bayer process, some of the organic matter will react and pass into the liquor. With the constant recycling of the liquor, the concentration of dissolved organic compounds will build up to some equilibrium level, determined by the relative rates of addition and removal from the system. Also during the course of recycling, particularly where digestion is carried out at high temperature and/or high caustic concentration, there will be degradation of the organic compounds from the complex 'humic acids' to simpler aromatic and aliphatic compounds. Over a period of time, a complex mixture of organic compounds becomes established in the process liquor. Two important end products of this degradation process are sodium carbonate and sodium oxalate.

The organic impurities have a number of effects in the process, such as:

- Increased density, viscosity and boiling point of the liquor.
- Increased solubility of alumina (causing reduced yield).
- Co-precipitation of sodium oxalate with the product aluminium hydroxide ('hydrate').
- Generation of foam.

All of these effects impair the efficiency of the process and may reduce the quality of the product.

From the point of view of impurity control, the problems can be placed in two categories:

- The general effects due to the presence of all organic impurities.
- The specific effects due to the formation and crystallisation of sodium oxalate.

The strategies required to deal with these two issues are quite different.

B. Analytical Methods

Before making any investigation of the issue of organics, it is first necessary to determine the levels present in liquors and raw materials using suitable analytical methods. These can be broadly classified, according to their purpose, as:

1. Methods for determination of total carbon content (organic and/or carbonate).
2. Methods for determination of oxalate
3. Methods for the identification and determination of other individual organic species.
4. Methods for determination of humates (high molecular weight).

The first two are essential, while the others are desirable for more detailed studies.

The analytical capabilities of the different laboratories visited in India varied widely. JNARDDC currently has no procedures in place. There is a plan to purchase a gas chromatograph which will be appropriate for the third type of analysis. Methods for the first two are also required. A comprehensive review was prepared in conjunction with Dr. K.V. Ramana Rao of JNARDDC to identify the most suitable procedures.

Of the plants, some are well equipped while others have only inaccurate procedures. The methods used are mainly of the 'classical' type, though modern instrumental methods are starting to appear. There is a need for the industry to work together with the JNARDDC to optimise its analytical capabilities.

C. Sources of organic impurities

The main source of organic impurities is the bauxite fed to the process. The data available on the carbon content of Indian bauxite does not appear very reliable. It is summarised in the Table below. Data for some foreign bauxites are included for comparison.

<u>Bauxite or Plant</u>	<u>C in bauxite</u>	<u>C input to process</u>
	%	kg t Al ₂ O ₃
BALCO	0.18	2.6
HINDALCO	0.25	7
NALCO	0.05-0.10	1.3-2.5
Boke (Guinea)	0.12	2.4
Weipa (Australia)	0.2	4.4
Darling Ranges (Australia)	0.26	8

By international standards, the carbon input to the older plants is in the medium range. The Panchpatmali bauxite (NALCO) has very low carbon content. Significantly, this style of bauxite is expected to be the basis for future expansion of the industry in India.

Another significant contributor to organics is the natural flocculant (starch or similar) used in most Indian plants. This can be wholly or partially eliminated by substitution with synthetic flocculants which are more stable and used in much lower quantities.

D. Impurities in the plants

Typical impurity levels in the different plants are indicated in the following Table. These data are obtained from the plants themselves and in some cases do not appear reliable. Some data for Queensland Alumina (Australia) are included for comparison.

<u>Plant</u>	<u>Caustic soda</u>	<u>Carbonate</u>	<u>Organic carbon</u>	<u>Oxalate</u>
	g/l Na ₂ O	% of soda	g/l C	g/l Na ₂ C ₂ O ₄
BALCO	140	11	4 ¹	8 ²
HINDALCO	105	21	9	3.7
INDAL	120		10	3
NALCO	145	13	3.6	0.55 ³
QAL	120	17	25	2.5-3

Notes:

1. This figure is too low: the author estimates the correct value to be in the range 15-20.
2. This figure is impossibly high.
3. This figure is unreasonably low.

Two conclusions may be reached:

- By world standards, the levels of organic impurities in Indian alumina refineries are in the low to medium range.
- In some cases, eg. BALCO, the of levels impurities are high relative to the ability of the technology to cope with them.
- Some refineries, notably HINDALCO, do have high levels of oxalate and or carbonate.

E. Problems in the plants

As noted in the introduction, impurity effects tend to fall in to two categories. The problems reported from the plants reflect this.

- BALCO has difficulties with liquor concentration (evaporation) and separation of carbonate and vanadate salts, due to high viscosity.
- All plants are to a greater or lesser extent concerned with oxalate and its effect on precipitation product yield and quality.

F. Control measures

The control measures adopted by the different plants vary widely:

- BALCO uses salt separation to remove carbonate and vanadium salts. This apparently removes some organics, but only a small amount.
- HINDALCO uses 'wet oxidation' for general reduction of organic impurities together with seed washing and crystal growth modifier (CGM) for oxalate control.
- INDAL currently has no controls but is looking for a suitable method to remove oxalate.
- NALCO has no controls and little apparent need at this time.

G. Precipitation

In the Bayer process, 'precipitation' is the name given to the stage in the process in which pure aluminium hydroxide (commonly referred to as 'hydrate') is crystallised from the supersaturated sodium aluminate liquor. It is a key stage in the process, substantially determining the purity and quality of the product alumina and the overall productivity of the plant. It is particularly sensitive to the effects of organic impurities. The main effects of organics are to increase the solubility of alumina and to decrease the rate of crystal growth. Both of these effects reduce the yield obtainable from the process. Sodium oxalate in the liquor also crystallises during precipitation. This may interfere with hydrate crystallisation and commonly causes an undesirably fine product. Correct particle size is a key quality for alumina.

The industry in India uses a range of precipitation technologies, including batch and continuous, American and European. Most of it must be considered obsolete.

IV. CASE STUDY

A case study for the Balco refinery was made by the author in conjunction with H.K. Chandwani and J. Zambo. This is attached as Annex 6 ("Organic Impurities at Balco Alumina Refinery: Situation and Options for Improvement"). The findings can be summarised as follows:

- The plant laboratory has inadequate analytical facilities. As a result, the real levels of organic impurities in the process could not be properly defined.
- The plant appears to be at equilibrium with respect to organic impurities.
- The level of organic impurities appears to be at or above that which is tolerable by the installed technology.
- The main problems with organic impurities are:
 - Impairment of the operation of the salt separation unit, which mainly removes inorganic impurities.
 - This is a major impediment to any intensification of the overall process.
- These problems could be addressed by:
 - Replacement of starch flocculant by synthetic flocculant.
 - Increasing the efficiency of the salt separation unit for the removal of both inorganic and organic impurities.
- Consideration should be given to redevelopment of the precipitation stage to improve product quality.

V. CONCLUSIONS

Overall situation

The levels of organic impurities in Indian bauxites and alumina refineries are in the low to medium range, by world standards. Plants with older technology may nonetheless have difficulty coping with these levels. The situation will improve as the industry takes further advantage of the low carbon bauxites of Orissa.

Knowledge of the problems

The industry has insufficient knowledge of the nature of the organic impurities, their effects on the process and of how these problems have been tackled elsewhere in the world. One problem here is that the literature is full of smart ideas that are not economically viable, while the simpler techniques that operators really use are rarely discussed. A more critical approach to the literature and personal contacts with other plant operators and researchers are therefore essential.

Inadequate analytical facilities are also a bar to effective identification of problems and solutions.

Current approach to solution

The current approaches have been either to do nothing (BALCO, NALCO) or tackle the problem head-on (HINDALCO). INDAL is now taking a more measured approach. In the case of HINDALCO, a decision was taken to reduce the overall level of impurities using wet-oxidation (Aluterv technology). This was effective in its primary purpose but had negative effects on the oxalate balance. Seed washing and, subsequently, CGM were introduced to control oxalate, but the situation is still unsatisfactory as the various impurity control methods do not appear to be properly balanced.

By contrast, the Australian industry operates with very high levels of impurities but makes little use of impurity reduction processes, which are not seen to be economic. Oxalate is carefully controlled, mainly by the simple method of seed washing. These plants are mainly based on American technology, which uses lower caustic concentrations and is less sensitive to impurity problems.

Precipitation

Most alumina refineries in the world now produce 'sandy' alumina. This is characterised by a low fines content, high strength, high surface activity and good flow properties. These properties are all necessary for use in modern aluminium smelters, particularly where 'dry scrubbing' is used for fume control. Precipitation technologies have been developed to produce alumina of this quality at high yield: examples are the Alusuisse method and modern developments of traditional American technology.

Because these technologies make active use of particle agglomeration to achieve a suitable particle size distribution, they have the ability to counteract the fining effects of organics and are so less sensitive to impurities. Systems for oxalate removal are almost always included as part of the technology.

While individual companies have their proprietary technologies, the general principles underlying them are now well known. The industry in India should be using this knowledge to improve its precipitation methods for better quality and less sensitivity to organics.

Recommended approach to solution

- Careful analysis of the real nature of the problems.
- Reduction of the amount of carbon input to the process, especially by substitution of synthetic flocculants for starch.

- Optimisation of salt removal systems (where available) to enhance the removal of organics.
- Careful attention to oxalate control by simple techniques, such as:
 - ♦ Product wash
 - ♦ Seed wash
 - ♦ Use of CGM where appropriate and economically justifiable
- The plants which are based on the American style of technology (HINDALCO & INDAL) should be able to take advantage of the many improvements to this technology which have been made in the past twenty years, examples of which are seen at QAL and Worsley.
- The plants with European technology (BALCO & NALCO) will need to take a different approach. The Alusuisse / Gove technology shows how such technology can be adapted for the efficient production of sandy alumina.
- In both cases, precipitation is a key area for development.

RECOMMENDATIONS

- JNARDDC must rapidly establish analytical techniques in the following areas:
 - ♦ Routine methods for internal use.
 - ♦ Robust routine methods for use in plant laboratories.
 - ♦ State-of-the-art methods for internal use and as a service to the plants.

The planned acquisition of a gas-chromatograph will fulfill some of this need.

- As part of this process, JNARDDC should immediately move to organise inter-laboratory tests to determine the accuracy and precision of the analytical methods currently in use, as a basis for choosing which methods are most suitable for future use.
- JNARDDC should develop a thorough knowledge of organic impurities through literature studies and interaction with the plants. Special attention should be given to the chemistry and behaviour of oxalate in the Bayer process.
- JNARDDC should build expertise in precipitation modelling and experimentation as a basis for the development of better precipitation technologies in the industry.
- The companies should support this development by entering into collaborative projects. These must be of suitable duration and properly funded.
- UNIDO can assist these processes by continuing to provide overseas travel opportunities to the research staff.

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

PROJECT IN INDIA

DP/IND/88/015/11-52/73207

JOB DESCRIPTION

- Title** Consultant in alumina production, especially in behaviour and treatment of organics in the Bayer process
- Duration** 3 months
- Time required** As soon as possible
- Location** Nagpur, India - with travel within the country
- Purpose of project** The immediate objective of the project is to assist the Government of India in setting up a functioning Aluminium Research, Development and Design Centre consisting of:
- a) Alumina Production Research Department
 - b) Aluminium Electrolysis Department
 - c) Analytical Research Department
 - d) General Services, Instrumentation and Control Department (incl. Workshop and Maintenance)
 - e) General Administration and Finance Department
- The Centre will develop capability of carrying out the following main functions on behalf of and in co-operation with the bauxite processing/alumina production and aluminium smelter industries in the country:
- a) Assimilation and adaptation of available technologies
 - b) Providing recommendations and ad hoc or applied and analytical research to local industries in process improvement, transfer of technology, etc.
 - c) Setting up and operating a data bank
 - d) Providing training of Indian engineers

..../..

Applications and communications regarding this Job Description should be sent to:

Project Personnel Recruitment Section, Industrial Operations Division

UNIDO, VIENNA INTERNATIONAL CENTRE P.O. Box 200, Vienna

Duties

The consultant will be required to provide consulting/advisory services on behaviour and treatment of organics in different stages of the Bayer process of alumina production and on methods of their removal from the production cycle.

His main duties will be to:

- 1. Deliver lectures and provide consultancy to the specialists of the Centre and the industry on the relevant subjects of organics in the Bayer process of alumina production: origin of organics in the process liquor, identification of organics in the bauxite and aluminate liquor, impact of organics on different stages of the process, methods of removal of organics from the production cycle.
- 2. Prepare a case study (in co-operation with the specialists from the Centre and the industry) on "Organics in Process Liquor, Impact on Production Efficiency and Possible Means of their Removal". The case study has to be for one of the alumina plants in India, selected by the consultant and counterpart.
- 3. Provide the Centre with information on the latest relevant technical literature and supply copies thereof.

The consultant is expected to prepare and submit a technical report with attached case study upon completion of his mission. The report should be prepared in line with UNIDO requirements.

Qualifications

University degree (preferably PhD) in chemical or metallurgical engineering, with extensive practical and research experience in study and treatment of organics in the Bayer process of alumina production.

Language

English

ANNEX 2**WORK PROGRAMME FOR CONSULTANCY AT
JNARDDC, NAGPUR****DR.P.J.CRESSWELL***19 January 1993***OBJECTIVES**

1. To review the "organic impurities" situation in the Indian alumina industry and make recommendations for improvements.
2. To provide consulting and training services in the field of organic impurities in the Bayer process.
3. To assist in the upgrading of the existing process mass balance model to allow variable temperature profiles in the precipitation area.

TIMING

Commencing 18 January 1993 for 11 weeks. All tasks are to be completed by the end of March 1993.

WORK PROGRAMME**ORGANIC IMPURITIES IN THE INDIAN ALUMINA INDUSTRY**

Contact: R.N.Goyal

1. Obtain information on the situation in the industry from JNARDDC staff and from plant visits. Topics to include:
 - Origin of organic impurities at the various plants
 - Composition of plant streams, sufficient to determine a mass balance for the organic impurities
 - Analytical methods, in use or proposed
 - Effects of impurities on the process, existing or foreseen
 - Methods for removal of impurities, in use or contemplated
2. Develop impurity balances for the plants and verify against plant data.
3. Review the overall situation and make recommendations for:
 - Ways to improve plant operating efficiency

- Project areas for development by JNARDDC
- 4. Prepare detailed case study for process improvement at one refinery.

CONSULTING AND TRAINING OF JNARDDC STAFF

Contact: R.N.Goyal, R.Rao

1. Prepare a bibliography of pertinent literature
2. Prepare notes summarising the knowledge in the field
3. Discussions with staff, both formal and informal
4. Deeper investigation of areas of special interest
5. Review analytical methods and make recommendations for future directions.(R.Rao)

HEAT/MASS BALANCE MODEL

Contact: M.J.Chaddha, Sharma

1. Assess existing precipitation model
2. Determine best method for modelling variable temperature profile
3. Implement in model
4. Verify against plant data

ANNEX 3*CONTACTS AT JNARRDC*

Dr. T.R. Ramachandran	Director
Dr. J. Zambo	Technical Adviser
R.N. Goyal	Head of Alumina Department
S.K. Chandwani	
Dr. K.V. Raman Rao	
Dr. A.K. Nandi	
Dr. K.V. Krishnan	
R.I. Sharma	
H. Mahadevan	
M.J. Chaddha	
V. Viswanathan	

ANNEX 4**INDUSTRY CONTACTS****BALCO**

P. R. Choudhury (Acting GM)

O.N. Sharma (Manager, R&D)

Kedarnath (Chief Manager, Alumina Technical)

A. Mehrotra (Manager, Alumina Technical)

R.S. Singh (Sr. Manager, White side)

HINDALCO

D.B.Rishi, Joint President (Alumina Plant)

T.A.Venugopalan, Joint President (R & D)

Raj Prakash Shah, General Manager (Alumina)

Dr.K.Chowdhury, Manager Laboratory

S.N.Gararia, Superintendent (Energy), Alumina Plant

INDAL

Dr. R.G. Kalbandkeri

NALCO

Dr.R.C.Mohanty, Addl. General Manager (M&R)

P.Vidyasagar, Dy. General Manager (Operation)

P.Das, Dy. General Manager (Operation)

V.K.Sood, Manager (Alumina)

J.S.Bedi, Addl. Chief Engineer (Chem)

B.K. Padhi

ANNEX 5**SUMMARY OF COMPANY VISITS**A. BALCO, KORBA REFINERY (MP)

28 - 31 January 1993

P.J. Cresswell accompanied by H.K. Chandwani (JNARDDC)

- Tour of the refinery and laboratories
- Discussions with plant management, operations and research staff
- Collection of data
- Seminar presentation "Precipitation and Impurity Control at Queensland Alumina"

The information gathered during this visit forms the basis for the Case Study (Annex 6).

B. HINDALCO, RENUKOOT REFINERY (UP)

18 - 20 February 1993

P.J. Cresswell accompanied by R.N. Goyal (JNARDDC)

- Tour of refinery and laboratories
- Discussions with plant management, operations and research staff

There was special interest here in the problems of impurities and of the potential for improvements to precipitation. The observations were summarised in a report to JNARDDC.

C. NALCO, DAMANJODI REFINERY (ORISSA)

23 - 25 February 1993

P.J. Cresswell accompanied by R.N. Goyal (JNARDDC) and N.G. Sharma (NALCO)

- Tour of mine, refinery and laboratories
- Discussions with plant management, operations and research staff

**JAWAHARLAL NEHRU ALUMINIUM RESEARCH
DEVELOPMENT AND DESIGN CENTRE,
NAGPUR**

**ORGANIC IMPURITIES AT BALCO ALUMINA REFINERY :
SITUATION AND OPTIONS FOR IMPROVEMENT**

Preparation of this case study has been part of the work programme for consultant in organics in the Bayer process

Prepared by Dr. P.J. CRESSWELL
UNIDO consultant

APRIL 1993

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CASE STUDY

ORGANIC IMPURITIES AT BALCO ALUMINA REFINERY : SITUATION AND OPTIONS FOR IMPROVEMENT

OBJECTIVES

- To assess the effects of organic impurities on the Balco alumina refinery.
- To make recommendations for control of impurities and improvement of the plant.

INTRODUCTION

BALCO (Bharat Aluminium Company) operate an alumina refinery at Korba, Madhya Pradesh. The plant was opened in 1973, using the technology of Aluterv-FKI, and has a rated capacity of 200,000 tonnes per annum of alumina. All of the alumina produced is consumed by the adjacent aluminium smelter. The refinery uses traditional 'European' technology, characterised by high temperature and caustic concentration in digestion and high solids precipitation, to produce a very fine alumina, typically 40% finer than 45 microns.

The BALCO smelter is currently upgrading its technology to reduce energy consumption. These changes may be incompatible with the present alumina quality. JNARDDC has therefore been preparing proposals to improve the refinery technology to allow production of a coarser product. As organic impurities in the process affect refinery operations and product quality, this study was initiated to determine the current situation in the plant and to make some recommendations for improvement.

The data upon which the study is based was mostly obtained during a visit to the plant by P.J. Cresswell and H.K. Chandwani in January 1993.

I. PLANT OBSERVATIONS

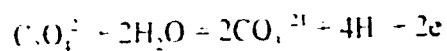
A. Analytical Methods

Determination of organic impurities in plant liquors is based on two procedures :

- a) Total organic carbon is determined by oxidation with acid permanganate. The evolved CO_2 may be absorbed in excess $\text{Ba}(\text{OH})_2$ solution and determined by titration. The simple method normally used is to add excess permanganate and then back-titrate with sodium oxalate. The result is expressed in terms of equivalent $\text{Na}_2\text{C}_2\text{O}_4$ g/l
- b) Oxalate is determined by oxidative titration with ceric sulphate using a ferroin indicator.

It is clear from the data (see below) that neither of these methods gives accurate results. The plant people are aware of this and use the results only as indicators.

The method for Total Organic Carbon appears to grossly under estimate the real value. Some under estimate is to be expected as the conditions are not sufficiently vigorous to oxidise all of the organic impurities. Acetate is particularly difficult to oxidise and typically accounts for about 25% of the total impurities. Another factor contributing to the error may be the use of back titration. This must make some assumption about the stoichiometry of the oxidation reaction, presumably that it is equivalent to the oxidation of sodium oxalate.



Because of the complex mixture of compounds being oxidised, the actual stoichiometry may be quite different.

The method for oxalate appears to grossly over estimate the true value. Again, some overestimate is to be expected because the method is not fully selective for oxalate and other easily oxidisable species will be determined as well. Better accuracy might be obtained by potentiometric measurement of the end point instead of the indicator.

Additional analytical data are available from some external sources, particularly Alutery.

B. Organic Impurities

Bauxite

The typical bauxite composition is given in Attachment 1. Average carbon figures for the past nine years are given in Attachment 2. The long term average is 0.18% C with no apparent trend. This can be considered a medium level (cf. Boké 0.16, Weipa 0.23).

Individual analyses of samples from several mines, are also given in Attachment 2. These are all around 0.14%.

The bauxite carbon is thought to be about 50% soluble in digestion.

Red Mud

Annual average values for carbon in red mud are given in Attachment 2. The long term average is 0.27% C with no trend other than a small drop in the past two years.

The typical composition of the filtered mud is given in Attachment 1.

Liquors

The current composition of plant liquors is given in Attachment 3. Caustic and mole ratio values for a number of different streams are given in Attachment 4. Annual average impurity levels in settler overflow and 'thickener overflow' (spent liquor) are given in Attachment 5.

The organic carbon content of the liquor is said to range from 20 to 30 g/L (expressed as equivalent $\text{Na}_2\text{C}_2\text{O}_4$) and is currently 24 g/L. This is clearly not accurate (see below).

Analytical data for oxalate in liquor appear scant. The current value in settler overflow is given as "about 8 g/L". Data from May 1991 showed values of 9.17 and 8.84 g/L for SOF and spent liquor, respectively.

Hydrate

Analytical data for hydrate are given in Attachment 6. Organic carbon in hydrate has been measured at 0.09%, alumina basis (Attachment 2). The hydrate has some colouration which may be due to contamination with either iron (0.046% as Fe_2O_3) or organics.

Alumina

Analyses of product calcined alumina are given in Attachment 7. The levels of Silica, Iron and Soda are high by world standards.

Salt Cake

The composition of the salt cake (approximate) is: V_2O_5 8%, P_2O_5 6%, Na_2CO_3 12%, NaF 3%. Organic carbon levels have been determined in the range 0.8 - 1.1% (Attachment 2).

The vanadium is said to precipitate as a complex salt with phosphate and fluoride. The

oxalate content of the cake has not been determined. One would expect precipitation of oxalate in the evaporator to be quite significant, particularly if the levels in the liquor are anywhere near those claimed.

Individual organics

A range of organic impurities in bauxite and liquor has been determined by Aluterv, presumably by gas chromatography (see Attachment 8). The main components in liquor are, in order : acetate, formate, benzene polycarboxylates, succinate and oxalate. The composition was judged to be similar to Hungarian plant liquor. It was observed by this author that the Balco liquor was odourless.

This is in contrast to liquors from Australian bauxites, which have a strong odour, possibly due to the presence of volatile amines. This indicates some qualitative differences between the organic species present in Indian and Australian bauxites. (A 'normal' odour was noted in subsequent visits to Hindalco and Nalco).

C. Inorganic Impurities

The inorganic impurity content of the SOF and spent liquors over the past five years are given in Attachment 5. All values are relative to a caustic concentration of 140 g L Na₂O.

Carbonate

The sodium carbonate concentration is in the range 25-30 g L. Total salt concentration (mainly carbonate) is about 10% of caustic. In "American" terminology this corresponds to a C/S ratio about 0.90. The carbonate level is controlled both by causticisation and by salting out. The figures indicate that this is sufficient to maintain a low carbonate level.

Silica

Silica concentrations in liquor are in the range 0.5-0.6 g L which is what one would expect for liquors of this concentration.

Silica in alumina is 0.035 % which is considered high. Silica in hydrate is 0.024 %, indicating that the silica contamination arises in precipitation, not in calcination. The data in Attachment 5 indicate a drop of 0.04 - 0.08 g L SiO₂ between SOF and spent liquor.

Assuming a yield of 65 g L Al₂O₃ in precipitation, deposition of this amount of silica would

made a hydrate with 0.06-0.12 % SiO_2 . This is well above the observed level, indicating that most of the silica is not precipitated on the hydrate.

Iron

Iron in Bayer liquors may be soluble, colloidal or as suspended matter (red mud) and the distinction between these forms is often difficult. One must assume that the impurity analyses (Attachment 5) are made on well filtered liquor so that only soluble and colloidal iron is determined. The observed concentrations are about 40 mg/L Fe_2O_3 in SOF and 20 mg/L in spent liquor, indicating precipitation of 20 mg/L. Again, assuming 65 g/L yield this would make a hydrate with 0.031% Fe_2O_3 , or 0.047 % on a calcined alumina basis. A recent hydrate analysis was somewhat higher than this (0.046 % Fe_2O_3 , Attachment 6) but average levels in alumina are in the range 0.049 - 0.055%, in general agreement with this estimate. This indicates that the bulk of the iron in alumina arises by precipitation of soluble or colloidal iron, with probably only a small contribution from suspended solids.

To have confidence in these estimates it is really necessary to have data on impurity levels in liquor feed to precipitation as there may be removal of soluble or colloidal iron at the Kelly filters. These data are not currently available.

Vanadium

The vanadium level in plant liquors is about 1.7 g/L as V_2O_5 . Control of this impurity is critical and is achieved by salting out as a complex vanadium, phosphorus, fluoride salt. The process of crystallisation and separation of the salt appears to be quite sensitive to changes elsewhere in the process. Because it is such an important part of impurity control at the Balco plant, the chemistry of this unit process should be better understood.

D. Precipitation

The precipitation area at Balco follows Alutery technology, using high caustic, high solids, low temperature conditions to produce a fine hydrate (alumina typically 40 % - 45 microns). Precipitation is continuous, with aluminate liquor (CAL) and recycled seed being mixed and then passed to a series of fifteen air-agitated tanks (typically 12 on line). Some of these are equipped with external heat exchangers to provide cooling. The product from the last precipitator is split into seed and product streams. The seed is filtered on disc filters and then

recycled. The product is filtered, washed and sent for calcination. The plant does have one or two cone classifiers but these are not in use.

Developments at the Balco Smelter require that the alumina be coarsened to about 20% fines. In the longer term it may be desirable to produce a sandy alumina with less than 10% - 45 microns. The problem facing the plant is how to achieve this coarsening. Trials in the past have shown that coarsening to 20% fines is possible by raising the precipitation temperature about 4°C, thus encouraging agglomeration. However, the trials showed that precipitation efficiency dropped about 5% and the process became unstable. Simply raising temperature is not an acceptable solution to the coarsening problem.

E. Process Problems due to organic Impurities

Foaming is an intermittent problem. High liquor viscosity causes a number of problems in evaporation and salt separation:

1. The high boiling point and viscosity reduce the efficiency of evaporation.
2. This results in lower caustic concentration in the digestion liquor, reducing yield.
3. Separation of impurity salts is impaired, so these tend to remain in the circuit.

Product quality is a major issue (excessive fines, high SiO_2 and Fe_2O_3) but this is probably not directly related to organics.

II. ASSESSMENT

A. Comments on the data

As mentioned in Section 2.1, the Balco laboratory does not appear to have adequate methods to accurately determine organic carbon and oxalate in process liquors. The values for carbon in bauxite and mud in Attachment 2a appear reasonable. Those for bauxite carbon in Attachment 2b are significantly lower, but consistent with the most recent data in Attachment 2a. This may reflect a real change or be an analytical artefact.

The current value for organic carbon in liquor is given as 24 g/L (as $\text{Na}_2\text{C}_2\text{O}_4$) which is equivalent to 4 g/L as C. For comparison, the Gove refinery, which has a relatively low level of organics, has 10-12 g/L C while QAL has about 25 g/L C. 4 g/L would be taken to be a

negligible content of organic impurities. However the liquors are highly coloured and from this one might judge the real carbon content to be in the range 20 ± 5 g/l C.

Some attempts have been made at Balco to develop a method for determining carbon in liquor using a Leco carbon analyser. This was apparently unsatisfactory, but values up to 17 g/l C were obtained in trials. This is consistent with the above estimate based on colour.

With oxalate, the situation is reversed. The concentration in liquor is quoted at about 8 g/l $\text{Na}_2\text{C}_2\text{O}_4$. Now the solubility of oxalate in Bayer liquor is quite well known. At 140 g/l Na_2O the equilibrium solubility will be less than 2 g/l and the 'critical oxalate concentration' (the metastable limit) will be around 3 g/l (about 2.8 g/l in QAL liquor). Hence a level of 8 g/l is a thermodynamic impossibility.

The levels of organic carbon and oxalate in Balco liquors must therefore be considered to be 'unknown'. Without this information, no serious discussion of the problems of organic impurities in the plant can be undertaken. The first priority for JNARDDC and the plant laboratory must be to establish reliable methods and to carry out an accurate survey of the organic impurities in the various plant streams.

B. Organic Carbon Balance

An estimate for the organic carbon balance in the plant can be made using 'best available data'.

The balance is reasonably good, considering the uncertainty in the input data. Some of the difference must be assigned to carbonate produced by degradation of organics in digestion and in the recirculating liquor. This will be removed by causticisation and in the salt cake. The carbonate content of the salt cake is 0.3 kg/t Al_2O_3 as C. It is notable that the balance is dominated by carbon entering in the bauxite and leaving in the red mud.

The balance suggests that organic impurities in the plant are at or near equilibrium. This is confirmed by data in Attachment 5, which gives levels of organic and other impurities for the last five years. While the absolute values for organic C cannot be accepted, the data do indicate stability between 1987 and 1990. The level appears to have increased by about 10% over the period 1990-1992. However, the data for January 1993 (Attachment 3) indicate a return to the earlier level.

CARBON BALANCE FOR BALCO REFINERY

	Specific Consumption per tonne Al_2O_3	% C	C input/output kg/t Al_2O_3
INPUTS			
Bauxite	2.6 t/t	0.18	4.68
Flocculant (Starch)	2.2 kg/t	35	<u>0.77</u>
Total inputs			5.45
OUTPUTS			
Red mud	1.44 t/t	0.27	3.89
Liquor	0.95 m ³ /t	0.05 g/l	0.05
Alumina	1.0 t/t	0.09	0.9
Salt cake	22 kg/t	1	<u>0.22</u>
Total outputs			5.06
Net input - output			0.39

C. Balco in the World Context

Until recently, Bayer process technology followed two distinct practices, the European and the American.

European

This was characterised by high caustic concentration in digestion to enable high productivity and low heat consumption. Precipitation was also carried out at moderately high caustic concentrations, low temperatures and high seed ratios. This generated a fine product suitable

for making flourey alumina. Impurity control was based on precipitation of impurities (principally sodium carbonate) from concentrated liquor (salting out). In this system, the main problem with organic impurities is the increase in liquor viscosity, which reduces the efficiency of evaporation and of the separation of the precipitated salts. Traditionally, European refineries processed local bauxites which had low levels of organic impurities.

American

The American practice was based on tropical bauxites which could be treated at lower temperatures and caustic concentrations. The lower caustic in precipitation created conditions favourable for generation of a coarser product which was lightly calcined to make sandy alumina suitable for prebake smelter cells. Energy consumption in digestion and evaporation was not a major concern because of the low cost of energy. Control of carbonate in this system was mainly by internal causticisation (addition of lime). As the source of alkali was often soda ash, it was in fact not possible to achieve high caustic concentrations. The tropical bauxites contain higher levels of organic impurities. The American technology is less sensitive to this, the main effect being a reduction in precipitation yield. Evaporation of liquors to high concentration is not required. Oxalate control is necessary to maintain control of particle size.

Modern Technology

In the past twenty years, a number of factors have changed the face of the alumina industry worldwide. Principal amongst these are:

- The emergence of coarse sandy alumina as the standard product, due to the evolution of smelter technology.
- Widespread use of tropical bauxites, with wide ranging characteristics requiring both high and low temperature treatments.
- A worldwide increase in the cost of energy.

As a result, a hybrid technology has emerged which attempts to bring the high productivity and energy efficiency of the European technology to the production of sandy alumina.

Examples can be seen in the Gove and Worsley refineries in Australia. These plants use caustic concentrations which lie between the European and American traditions. They remain relatively insensitive to organic impurities and can tolerate high levels (25 g/l Ca)

Worsley). Product quality is ensured by active control of particle agglomeration and oxalate removal.

Balco

The process used at Balco embodies classical European technology. However, in treating a bauxite with medium level of carbon (say 0.15%), it appears to be at or beyond the limit of this technology's ability to cope with impurities. This poses both immediate and long term problems.

D. Future Development at Balco

Technological development at Balco can take one of two directions:

- Maintain current product quality (or slight improvement) but increase productivity.
- Move towards production of a world standard product.

Increase in productivity requires the intensification of both digestion and precipitation. There are three key process parameters to consider:

- Caustic concentration in digestion.
- Molar ratio in digestion (at blow-off).
- Molar ratio in the precipitation feed (aluminate liquor).

The first of these may be directly limited by evaporation efficiency. The other two are limited by the efficiency of alumina extraction in digestion and the stability of the resulting liquor.

It is well known that both extraction efficiency and liquor stability can be increased by the addition of lime. Lime addition at Balco has also been proposed for control of iron in liquor. However lime also reduces phosphorus in the liquor, which is required for formation of the complex vanadium salt in the existing salting out process. Thus, every attempt to introduce lime to the digestion or clarification areas upsets impurity removal and has to be abandoned. It is absolutely necessary, therefore, to modify the salting out process to get around this impasse. Possible methods are considered below.

Development of a coarser product is also considered.

III. POTENTIAL METHODS FOR IMPURITY CONTROL

The immediate needs of the plant can be identified as follows:

- To increase the efficiency of evaporation and salt separation.
- Control of oxalate to assist the product coarsening project.

The basic strategy in the first case can be based around:

- Reduction of impurity input to the process.
- Enhancement of impurity removal.

The following sections examine the potential impact of several options on the impurity situation.

A. Flocculant

The plant currently uses starch flocculant (maize) which introduces about 0.8 kg C t Al_2O_3 . Most of this will be removed with the red mud. A change to synthetic flocculant, which is used at much lower dose rate, would almost eliminate this source of carbon input. It has also been observed that red mud flocculated with synthetic flocculant has greater surface activity for absorption of organics. The removal of C from the plant in red mud can therefore be expected to be maintained or increased. Hence we can expect a negative effect on the carbon balance amounting to 0.5 - 1 kg C t Al_2O_3 (10 - 20 % of the total). Over time this will lead to reduction in the carbon inventory in the liquor. The data are insufficient to predict what the new equilibrium level might be.

B. Lime

Addition of lime to digestion is proposed to improve extraction efficiency and increase liquor stability, allowing a significant reduction in SOF mole ratio. This is a key issue in increasing productivity at the plant (see above). Addition of lime will also affect impurities. The main expected effect is reduction of Fe, P, Ti and carbonate in liquor. One can expect some reduction in organics by absorption on the precipitated calcium salts. The main problem comes in the effect on control of vanadium in the salt separation plant.

C. Salt Separation.

Salt separation is used to control vanadium by precipitation of a complex V,P,F salt from concentrated liquor. Effective operation of this unit appears to be critical for smooth running

of the plant. The salt cake also contains some sodium carbonate (12%) and organics (about 1% C). This organic content seems rather low and it should be possible to increase it, making the salt separator a more effective contributor to the overall carbon balance (currently only 0.2 kg C t Al₂O₃).

A problem with the salt removal system is that the presence of organic impurities, by raising the viscosity, reduces the liquor concentration achievable by the evaporators and impairs the separation of the precipitated salts. Above some level (undefined in this case) this may lead to a vicious circle of increasing organics and diminishing effectiveness of the impurity control system. There may be a need to reduce the organics to a level where salt separation can again be effective. This may be done on a 'once off' basis using absorbents, such as activated carbon, or by improvements to the equipment. The concentration problem may be addressed by modification of the evaporators to include forced circulation.

The incompatibility with lime may be fixed by changing the chemistry of the salt. In the absence of phosphorus, vanadium can be precipitated as a sodium fluoro-vanadate. This occurs at lower temperatures (20-25 °C) so that it is necessary first to chill the liquor. Thus the benefits of lime use can be enjoyed without compromising impurity control.

The basic physics and chemistry of the salt separation stage needs to be better understood, both to ensure effective control of V in the face of process changes and to develop its potential for removal of organics.

D. Seed or Product Wash

Hydrate washing is well established as the simplest and most effective method for oxalate control. The oxalate bearing hydrate is first deliquored and given a displacement wash with cold water to selectively remove adherent liquor, while minimising the dissolution of oxalate at this stage. It is then washed with hot water to dissolve the sodium oxalate. The aim is to produce a wash liquor with a high concentration of oxalate and low concentration of caustic, which can be causticised with lime to precipitate calcium oxalate and recover soda. The operation can be carried out on drum or belt filters. Permanent disposal of the calcium oxalate is a problem which must be taken into consideration.

In the Kaiser technology, the target stream for seed washing is the tertiary thickener underflow, which may contain up to 3% sodium oxalate.

Product washing is an attractive alternative because this stream will be washed in any case and the process can be adapted for oxalate control with minimal additional equipment or water usage.

In any particular plant, it is first of all necessary to establish the concentration of oxalate in the various streams to determine the most cost effective method for control.

E. CGM

Crystal growth modifiers (CGM) are becoming a standard part of the operation of Bayer process precipitation circuits. However their mode of action, optimal formulation and method of use are still not well understood. They do not have a direct effect on impurity levels. The main effect seems to modify the interaction between the crystallisation of sodium oxalate and hydrate. This results in a stabilisation of crystalliser operations by enhancement of agglomeration and reduction in fines.

CGM tends to be seen as a 'magical' cure for plant problems. It is a relatively expensive additive, but the real benefits are difficult to quantify. Assessment of the effects of CGM at Balco should be based on a comprehensive research programme of laboratory batch precipitation trials. The "bottle" procedure is most suitable for this. The tests should preferably be done at the plant to ensure that the liquor and seed used are fresh.

F. Liquor burning and wet oxidation.

Wholesale reduction of organic impurities can be achieved by techniques such as liquor burning (eg. Alcoa, Kwinana) and wet oxidation (Hindalco). In practice, such methods are rarely used due to the expense and complexities of the operations.

Given the availability of a concentrated liquor stream from the salt separator (280 g/l Na₂O), either of these options could be considered at Balco. Effective removal of organics would be obtained by treating only a fraction of the strong liquor stream (probably less than 5%). The costs and benefits of either of these approaches would require careful analysis before a firm recommendation could be made.

III. POTENTIAL METHODS FOR PRECIPITATION IMPROVEMENT

The precipitation unit at Balco produces a very fine product (46% fines) at a yield of 65-68 g/l. This may be compared to 'world standard' operations producing less than 10% fines at over 70 g/l yield.

Two areas can be identified for improvement:

- Yield and/or production
- Quality

A. OPTIMISING THE YIELD OF THE EXISTING OPERATION

The options for increasing the yield were investigated using a simple model ("PPJN" written by P.J. Cresswell). Plant performance data for November 1992 were used to establish a base case for the calculations. The effects of varying individual process parameters were then determined, to identify those which have greatest potential to benefit productivity. The results are summarised in the following Table.

BASE CASE: NOVEMBER 92

CAL	141.0 g/l, 1.68 MR
Temperature, °C	Start 67, Finish 50
Last tank solids	370 g/l

EFFECTS OF PROCESS PARAMETER CHANGES ON YIELD:

CASE		YIELD	GAIN	PROD
		g/l	g/l	t/h
Base (as above)		68.3	-	38.0
Decrease feed ratio	1.65	70.7	2.4	39.5
	1.6	75.1	6.8	
Decrease start temp.	58 -- 50°C	68.6	0.3	38.1
CGM: Increase growth rate	20%	70.0	1.7	39.2
	40%	71.4	3.1	40.2
Increase solids	460 g/l	69.9	1.6	39.0
Decrease solids	300 g/l	66.3	-2.0	36.9
Coarsen solids	20%	66.3	-2.0	36.8
Increase seed filter solids (1388-1600 g/l)		68.8	0.5	38.4
Increase flow rate	20%	66.1	-2.2	44.0 (-16%)

Clearly, the greatest scope for increasing productivity comes from a decrease in the molar ratio of the feed liquor (ie. increasing the alumina content). This ratio is currently very high due to dilution of the blow-off slurry with spent liquor.

The effects of other parameters such as temperature and seed content are small. This comes as no surprise, as the plant already operates at low temperature and high seed content, so there is little room for improvement. There may be scope for optimisation of the temperature profile.

B. Product Coarsening

Two options may be considered for coarsening the Balco product:

1. Product 20-30% fines: this should be achievable using the hydroseparator only with no loss of yield. Implementation could be similar to the Pechiney method used at Nalco (see below).

2. Product <10% fines: to convert the plant to world standard product would require full classification and agglomeration, as typified by the Alusuisse technology. This coarsens the seed and can be expected to result in some loss of yield (say 2-3 g/l).

Pechiney

The Pechiney approach to the problem has been described by Cristol and Mordini. They use a special high solids classifier (Turbiflux) treating a portion of the product stream to separate a product with low fines (7-10% - 45 microns). This type of classification has the effect of decreasing the stability of the process, increasing the amplitude of fine - coarse swings. This has been controlled by carefully monitoring nucleation in the process and manipulating the starting temperature to ensure that nucleation and agglomeration remain in balance.

This technology is currently in use at NALCO (Damanjodi). Experience there indicates that it is not the ideal solution as this plant has also some problems with yield and product quality.

Alusuisse Technology

The Alusuisse technology has been described in numerous publications and patents. It was developed during the late 1970's for the Nabalco Gove refinery in Australia in order to convert that refinery's output from floury to sandy alumina. The original plant design featured traditional European precipitation technology, essentially the same as that now used at Balco. The essential changes were :

- a) installation of classification for products and seeds
- b) separate agglomeration of fines.

The classification area uses hydrocyclones, thickeners and seed filters. Agglomeration is tightly controlled to maintain a coarse particle size. Liquor productivity at the plant is very high, 80-90 g/l Al_2O_3 , but this is mainly due to the very high concentration of alumina in the feed liquor (about 0.74 A.C., 1.3 MR). The original design used only natural cooling, but interstage cooling has recently been installed to allow for expansion of the plant capacity. There is no direct control of organic impurities at the plant, but these are naturally low (10-12 g/l organic C in liquor). DADMAC or CGM may be used. Oxalate is sometimes a

problem as it remains in the pond water (which is recycled) and may reach quite high concentrations during the dry season.

RECOMMENDATIONS

- JNARDDC Should establish reliable methods for the determination of organic carbon and oxalate in Bayer liquors for use at the centre and for transfer to Balco. The range of methods available is currently under review by Dr Ramana Rao.
- Using these methods, JNARDDC and Balco should determine organic carbon and oxalate in the various plant streams and develop a mass balance for the organic impurities.
- JNARDDC and Balco should establish a collaborative project to determine the cause of the high iron content of the product alumina and to develop and implement a solution.
- JNARDDC and Balco should establish a collaborative project to investigate the fundamental chemistry of the salt separation unit with the following aims:
 - ♦ To maximise the efficiency of the unit for removal of vanadium and organic impurities
 - ♦ To maintain efficient operation of the unit when changes are made elsewhere in the circuit.

List of Attachments

1. "Information on Korba Refinery" compiled by Balco Staff in response to request by P.J. Cresswell.
2. a) Organic C in Bauxite and Mud (Annual Averages).
b) Organic C in Various Samples (September, 1993)
3. Composition of Plant Liquor (January 1993).
4. Composition of Various Plant Streams (Monthly Averages July-December, 1992).
5. Liquor Impurities (Annual Averages).
6. Analysis of Balco Hydrate (January 1993).
7. Quality of Alumina (Annual Averages).
8. Determination of Individual Organics in Bauxite and Liquor.

INFORMATION ON KORBA REFINERY (Prepared by Balco staff).

1. **Bauxite** - Bauxite is procured from 20-22 different mines. Detailed analysis of bauxite so procured is not available. However when blended the bauxite quality range is as under :

LOI	-	22 - 24 %
SiO ₂	-	2.5 - 4.0 %
Fe ₂ O ₃	-	15 - 18%
TiO ₂	-	6 - 9 %
Al ₂ O ₃	-	46 - 48 %
P ₂ O ₅	-	0.15 - 0.19 %
V ₂ O ₅	-	0.16 - 0.20 %
C-org	-	0.10 - 0.12 %

The composition range is fairly uniform all these years and approx. annual consumption rate is 5.0 lakh tonnes.

2. **Digestion** : A slurry flowrate to a maximum of 320 M³/Hr. is maintained. The slurry contains around 170 gpl Na₂O₃ and 87 gpl Al₂O₃ with a solid content of 200 gpl at the inlet of desilication. Impurity level before and after digestion is tabulated and enclosed.

Desilication is a series of tanks where slurry is held for 6-8 hrs. at 95 °C.

3. **Clarification** : Maize starch is the flocculant used at a rate of 1.5 kg/t of mud. No other additive is used.

Around 30 t/hr mud is filtered out with the composition being as under.

LOI	-	11 - 12 %
SiO ₂	-	7 - 8 %
Fe ₂ O ₃	-	33 - 36 %
TiO ₂	-	14 - 16 %
Al ₂ O ₃	-	14 - 16 %
P ₂ O ₅	-	0.22 - 0.25 %
V ₂ O ₅	-	0.22 - 0.25 %
Na ₂ O ₃	-	4 - 5 %
CaO	-	10 - 12 %

The return water from the pond is analysed for only Na_2O_4 content - 4 to 5 gpl depending upon the water level in pond. The pond water consumption is 30 - 40 M³/hr. approx.

4. **Precipitation** : Aluminate liquor flowrate is in the range of 350-370 M³/hr containing 140-141 gpl Na_2O_4 & 138-139 gpl Al_2O_3 . Facility for measurement of seed streams do not exist.

Temperature profile and performance data is enclosed.

Temperature profile is regulated by cooling of slurry through interstage coolers, with industrial water being the cooling medium.

5. **Impurity Control** : Simple causticisation consists of a series of pass-over tanks, generally four in line, where last washer mud, with a 20 gpl Na_2O_4 concentration and around 350 gpl solid content, is fed along with lime slurry. Live steam/flushed steam is used for maintaining the temperature above 95°C. No lime is added at digestion stage.

For salt separation, strong liquor from evaporation is cooled by heat exchangers and led to a thickener where a holding time of 4-5 hrs. is available. The settled salt is centrifuged and marketed. Salt contains approx. 7-8% V_2O_5 & 10-12 % Na_2CO_3 .

6. **Problems** :

- a) **Precipitation yield** : It is poor if we try to generate a coarse product -
(-) 325 mesh around 25%
- b) **Precipitation control** : Lack of analytical facilities for determination of seed area, no segregation/classification facility of seed.
- c) **Product quality** : off white colour and fine grain size.
- d) **Foaming** : Very dominant at times in ppt. circuit.
- e) **Oxalate Control** : Not much of a problem as the level of oxalate is low.

Attachment 2Organic C in Bauxite and Mud (Annual Averages)

Year	Bauxite %	Mud %
83 - 84	0.172	0.272
84 - 85	0.176	0.277
85 - 86	0.221	0.274
86 - 87	0.189	0.298
87 - 88	0.182	0.267
88 - 89	0.204	0.265
89 - 90	0.157	0.270
90 - 91	0.152	0.240
91 - 92	0.148	0.233
Overall Average	0.178	0.266

Organic C in Various Samples (September, 1991)

	% C
Bauxites :	
Amarkantak	0.140
Phutkapahar	0.137
Lohar Daga	0.144
Keshkal	0.133
Process bauxite	0.140
Nalco bauxite	0.153
Product hydrate (alumina basis)	0.09
Filter causticised mud	0.22
Soda Salt (centrifuge)	0.828
Soda Salt (non-centrifuge)	1.127
Soda Salt (monthly composite)	0.77
Pond return water (Na ₂ O 2.41 gpl)	0.0128 g L.
Settler overflow (Na ₂ O 145.7 gpl)	32.16 g L as Na ₂ CO ₃

Composition of Plant Liquors (January 1993)

All g/l. except as otherwise noted

	Settler Overflow	Spent Liquor
Na ₂ O (Caustic)	142.6	133.3
Al ₂ O ₃	132.6	65.29
MR (mole ratio)	1.77	3.30
<u>Impurities - relative to caustic at 140 g/L.</u>		
Na ₂ CO ₃	28.0	27.1
Na ₂ CO ₃ (as Na ₂ O)	16.4	15.9
Salt level, %	10.47	10.18
V ₂ O ₅	1.72	1.65
P ₂ O ₅	1.58	1.53
Organic C (as Na ₂ C ₂ O ₄)	24.34	23.53
SiO ₂	0.54	0.48
Fe ₂ O ₃ , mg/l	46.3	13.99
Na ₂ C ₂ O ₄	8	

ATTACHMENT - 4

BALCO LIQUOR ANALYSES (JULY - DEC 1992)

Months	Ingn. liquor		B.O.		SOF		CAL		1st Precipitator			Last Precipitator			Spent Liquor		Strong Liquor
	Concn. g/l	M/R	Concn. g/l	M/R	Concn g/l	M/R	Concn. M/R g/l	Concn. g/l	M/R	Solid g/l	Concn. g/l	M/R	Solid g/l	Concn. g/l	M/R	Concn. g/l	
July	170.9	3.26	192.5	1.57	140.5	1.69	140.1	1.70	140.4	2.09	281	142.9	3.27	345	135.7	3.27	241.2
Aug.	167.4	3.33	185.2	1.56	140.5	1.69	140.1	1.69	138.9	2.13	260	139.7	3.33	343	134.0	3.31	235.2
Sept	168.0	3.47	185.2	1.53	139.9	1.66	139.4	1.66	138.4	2.21	293	139.2	3.45	355	132.9	3.45	236.9
Oct.	169.8	3.44	189.3	1.55	140.3	1.67	140.0	1.67	140.1	2.19	322	141.0	3.41	380	135.0	3.41	322.0
Nov.	165.8	3.39	187.4	1.55	140.1	1.68	140.1	1.68	139.4	2.15	322	140.6	3.37	398	135.0	3.39	240.0
Dec	169.1	3.12	187.0	1.54	140.5	1.68	140.7	1.67	139.9	2.12	290	141.0	3.09	382	135.8	3.12	236.0

LIQUOR IMPURITIES, #/l (Annual Averages)

Year	Sillier Overflow								SPENT LIQUOR							
	Na ₂ CO ₃	Na ₂ CO ₃	P205	V205	C-org.	Fe203	SiO ₂	SaltX	Na ₂ CO ₃	Na ₂ CO ₃	P205	V205	C-Org.	Fe203	SiO ₂	Salt X
1981-82	32.75	19.11	0.87	2.10	25.44	33.45	0.58	12.02	32.24	19.51	0.82	2.03	25.38	12.8	0.50	12.27
1982-83	28.72	16.80	1.41	1.95	24.08	41.6	0.65	10.67	28.42	16.64	1.41	1.86	23.41	19.0	0.61	10.55
1983-84	29.82	15.12	1.50	1.83	25.14	37.37	0.58	9.71	25.90	15.11	1.50	1.75	24.78	22.31	0.50	9.72
1984-85	28.16	15.30	1.49	1.78	26.59	40.50	0.60	9.85	25.49	14.91	1.47	1.76	24.74	19.0	0.55	9.65
1985-86	28.74	15.62	1.53	1.70	28.21	37.52	0.55	10.07	26.31	15.33	1.48	1.63	27.33	15.91	0.48	9.91

Attachment 6Analysis of Balco hydrate

Average of daily composites, 1-15 January 1993.

		%
Moisture		8.5
SiO ₂		0.024
Fe ₂ O ₃		0.046
Na ₂ O (Soluble)		0.083
Na ₂ O (Total)		0.35
Size, mesh	+ 150	11.6
	- 150 + 200	22.0
	- 200 + 325	28.0
	- 325	38.5
Bulk density, kg/m ³		1254

* QUALITY OF ALUMINA *
%

Year	Adh. Moist.	LOI	SiO ₂	Fe ₂ O ₃	TiO ₂	P ₂ O ₅	V ₂ O ₅	Na ₂ O-T	BD kg/m ³	α		+ 150-150	- 200	- 325	
										K-1	K-2				
1988-89	1.01	0.57	0.037	0.055	0.013	0.003	0.007	0.48	1028	32	26	5.1	15.0	47.9	32.0
1989-90	1.12	0.63	0.035	0.052	0.011	0.0035	0.008	0.47	1028	31	26	3.9	13.8	40.2	42.1
1990-91	1.37	0.71	0.036	0.051	0.013	0.004	0.009	0.49	1093	31	29	5.6	15.8	40.0	38.8
1991-92	1.16	0.87	0.033	0.049	0.013	0.003	0.008	0.44	1087	33	28	3.5	13.2	39.4	43.6

Determination of Individual Organics

Alutery, 1977

<u>Component</u>	<u>Bauxite, ppm</u>	<u>Liquor, C/L</u>
Formate	92.3	0.7
Acetate	149	1.78
Propionate	2.1	0.09
Butyrate	1.5	0.025
i-Valerate	0.6	0.005
n Valerate	1.1	0.015
Oxalate	187	0.16
Succinate	9	0.26
Benzoate	0	0.008
Glutarate	0	0.022
Phthalate	1.6	0.03
Benzene tri-carboxylate	10.1	0.23
Benzene tetra-carboxylate	23.9	0.19
Benzene penta-carboxylate	15.3	0.13
Benzene hexa-carboxylate	13.8	0.007