Global Bromine Industry
And
Its Outlook

- Production by Country, Production Process, Application and Forecast.

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5. 9. 2008
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Brief description: bromine is the only liquid nonmetallic element. It is a member of the halogen group. It is a heavy, volatile, mobile, dangerous reddish-brown liquid. The red vapor has a strong unpleasant odor and the vapor irritates the eyes and throat. It is a bleaching. When spilled on the skin it produces painful sores. It is a serious health hazard, and maximum safety precautions should be taken when handling it.

Table: basic information about and classifications of bromine.
Name: Bromine
Symbol: Br
Atomic number: 35
Atomic weight: 79.904 (1)
Standard state: liquid at 298K
CAS Registry ID: 7726-95-6
Isolation

- Isolation: bromine is available commercially so it is not normally necessary to make it in the laboratory. Bromine also occurs in seawater as the sodium salt but in much smaller quantities than chloride. It is recovered commercially through the treatment of seawater with chlorine gas and flushing through with air. In this treatment, bromide is oxidized to bromine by the chlorine gas. The principle of oxidation of bromide to bromine is shown by the addition of a little chlorine water to aqueous solutions of bromide. These become brown as elemental bromine forms.

\[ 2\text{Br}^- + \text{Cl}_2 \rightarrow 2\text{Cl}^- + \text{Br}_2 \]

- Small amounts of bromine can also be made through the reaction of solid sodium bromide, NaBr, with concentrated sulphuric acid, H\(_2\)SO\(_4\). The first stage is formation of HBr, which is a gas, but under the reaction conditions some of the HBr is oxidized by further H\(_2\)SO\(_4\) to form bromine and sulphur dioxide. This reaction does not work with the corresponding chlorides and fluorides.

\[ \text{NaBr (s)} + \text{H}_2\text{SO}_4 (\text{l}) \rightarrow \text{HBr (g)} + \text{NaHSO}_4 (\text{s}) \]

\[ 2\text{HBr (g)} + \text{H}_2\text{SO}_4 (\text{l}) \rightarrow \text{Br}_2 (\text{g}) + \text{SO}_2 (\text{g}) + 2\text{H}_2\text{O (l)} \]
Israel: views from the Negev region

May 1999
The Dead Sea
Raw material harvester
An Introductory Presentation

Bromine Compounds Plant - Netherlands

Bromine/Chlorine Plant - Israel

23/11/00
BROMINE ISOTANKS ROUNDTripp IMPROVEMENT
Where Has the Market Share Gone? To China…

Aerial photo of Bromine production area in Shandong

Chinese Bromine production and packing facility
Bromine Production - India

Indian evaporation pond

Indian plant
Emerging Ukraine

Satellite photo of relevant Ukrainian regions

Ukrainian bromine plant
Bromine Concentration by Source

- **Dead Sea Brine**: 10-12 g/l
- **Brine Wells (USA)**: 2-6 g/l
- **Lake (India)**: 3-4 g/l
- **Shallow Sea (Ukraine)**: 0.6-1 g/l
- **Underground Wells (China)**: 0.2-0.3 g/l
- **Sea Water (China, Japan)**: 0.05 g/l

Source: ICL estimates
Global Bromine Production Capacity - by Region (700 KMT)

- USA, 215, 31%
- China, 150, 21%
- Others, 50, 7%
- Dead Sea, 285, 41%
Production Flow in ICL-IP

Production Flow

- Salt
  - Chlorine Production
  - Chlorine from Magnesium Production
  - Compounds Production (Holland)
  - Bromine Compounds (Sales)

- Dead Sea
  - Bromine Production
  - Chemicals
  - Bromine Compounds (Israel)

- Brine
  - Bromine (Sales)

- Steam

- Electr.

- Caustic Soda (Sales)
LEGEND: Bromide-enriched Dead Sea brine (1), heated by preheaters (A) and heat-exchanger (B), flows into a reaction column (C) in which the introduced chlorine (2) liberated elemental bromine. Steam (3) is used to strip the bromine out of the reaction column and into a condenser (D). From which the bromine flows into a phase separator (E). The bromine-saturated water (4) is returned to the reaction column, while the bromine (5) passes, first, to a distillation column (F). After cooling, the purified liquid bromine flows to storage (6),
Global Bromine Compounds Market - by Major Application (Total in 2007 - $2.5 BN)

- FR, 1400, 56%
- Agro (Fumigants), 130, 5%
- Industrial, 250, 10%
- CBF, 230, 9%
- Organic Interm., 300, 12%
- Water Treatment, 210, 8%
Bromine Compounds Consumption – By Region ($2.5 BN - 2007)

- **USA, 660, 25%**
- **Europe, 450, 18%**
- **China, 450, 18%**
- **Rest of Asia, 480, 18%**
- **ROW, 200, 8%**
- **Japan, 320, 13%**
Demand by Application (In terms of Bromine – 575 KMT in 2007)

- Agro-Fumigants: 25, 4%
- Industrial: 105, 18%
- Organic Interim: 63, 11%
- CBF: 67, 12%
- Water Treatment: 32, 5%
- FR: 283, 49%
Use of Bromine Compounds

- Flame retardants
- Agrochemicals
- Water treatment chemicals
- Pharmaceuticals and cosmetics
- Lead scavenger in anti-knock fuels
- Oilfield completion fluids
- Photographic chemicals
- Desiccants for cooling systems
- Bleaching and oxidizing chemicals
- Dyestuffs
- Monomers for specialty polymers
- Precision cleaning
Electrical and electronic continues to improve the quality of our lives.
Flame Retardants Worldwide Market

2,700 MM$ in 2005 – Bromine 38%

Miscellaneous include: inorganic phosphates, melamine, Mg(OH)₂, boron and Molybdenum compounds
February 14th 2005

100m high Windsor Tower in Madrid catching fire and completely destroyed.
Every day in Europe:

- 12 fire victims and 120 severely injured
- 75% of victims are in their homes
- Economic damage: +/- 25 billion Euro’s per year

In the UK since 1988 furniture regulation:

- 3200 lives saved 1988-2000
- 29000 less non-fatal injuries

Flame retardants and other technologies are a critical part of the fire safety solution.

The fire on an old (1980’s) European TV self-extinguishes, while the fire in a non fire-safe TV, recently sold in Europe, keeps burning and growing.
German Dioxin Ordinance, 16.7.1999

2, 3, 7, 8, - TBDD
1, 2, 3, 7, 8, - PeBDD
2, 3, 7, 8, - TBDF
2, 3, 4, 7, 8, - PeBDF 4 together: 1 ppb max.
Above 4 plus below 4 = Total 8: 5 ppb max.
1, 2, 3, 4, 7, 8, - HxBDD
1, 2, 3, 7, 8, 9, - HxBDD
1, 2, 3, 6, 7, 8, - HxBDD
1, 2, 3, 7, 8, - PeBDD
<table>
<thead>
<tr>
<th>RESIN</th>
<th>Br-FR</th>
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<tbody>
<tr>
<td>ABS</td>
<td>Deca, TBBA, Br-PC Olygomer, TAIC-6B, BEO, Br-PS, Ethylene-Bis(Tetrabromptalimide)</td>
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<td>Decabromodiphenylethane, Tris(TBNPA)phosphate Br-Aromatic Triazine</td>
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<td>EPS</td>
<td>TBBA-Bis(Allylether), HBCD TBP-Allylether, Tetrabromomethane</td>
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<td>HIPS Deca, TBBA, HBCD, Ethylene-Bis(Tetrabromptalimed)</td>
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<tr>
<td></td>
<td>BEO, Tris(TBNPA)phosphate Decabromodiphenylethane Br-Aromatic Triazine</td>
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<tr>
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<td>TBBA-Bis(2,3Dibrompropylether)</td>
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<tr>
<td>Material</td>
<td>Description</td>
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<td>PP</td>
<td>TBBA-Bis(2,3Dibrompropylether) Deca, TBBS, HBCD TBBS-Bis(2,3Dibrompropylether) Decabromdiphenylethane Tris(TBNPA)phosphate Br-Aromatic Triazine</td>
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<td>Components</td>
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<td>NYLON</td>
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<td>PVC</td>
<td>Deca</td>
</tr>
<tr>
<td>EPDM</td>
<td>Deca, Decabromodiphenylethane</td>
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</tbody>
</table>
EPOXY (laminate, BEO,)
- Deca, HBB, TBBA, TBP, BEO,
- Br Aromatic Triazine
- Dibromcrotylglycidylether
- Dibromphenylglycidylether

Phenol
- TBBA, TBP, BEO

URETHANE FOAM
- DBNPG, TBNPA, TBBA-2EO

URETHANE ELASTOMER
- Deca, BEO

UPET
- TBBA-2EO, DBNPG, TBNPA, BEO

DCPD
- Deca, Br-PS

Silicone (Rubber)
- Deca, Decabromdiphenylyethane
TEXTILE (Acrylic, SBR, PP, Polyester, Cotton)

Deca, HBCD, Pentabrom toluene
TBBA-2EO
Tris(TBNPA)phosphate

Adhesive, Adhesive Tape, Paper, Paint, Ink
Plywood

Deca, TBBA-2EO, HBCD
Ammonium bromide
Tris(TBNPA)phosphate
Decabrom diphenylethane
The demand for bromine based products will grow at an average rate of 2-2.5% per year (2% in the first 3 years and later 2.7%)

- Major drivers and growth areas:
  - Adoption of fire safety regulation.
  - New applications (Mercury reduction, ....)
  - Organic growth in the various applications, following growth of the global economy.

- Offset by:
  - Continued phased-out of MBr
  - Decline of Deca and HBCD
  - Emergence of non-halogen substitutes for BFR’s.
Reference

1. ICL-IP Slides, Estimated by ICL-IP
2. ICL-IP HP
3. ICL-IP Catalogue
4. VECAP Eco-Design Presentation, Hirayama

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