

BIOSORBENT MATERIALS FOR METAL REMOVAL/RECOVERY

MARKETS FOR ION EXCHANGE RESINS AND BIOSORBENTS

The major competing technology for the family of new biosorbent products is that based on well established ion exchange resins. Ion exchange technology has been developing over the period of past five decades and it is considered a mature area marking a gradual but limited growth as the case is for all well developed technologies. In order to assess the potential immediate market share of the new biosorbent products which use the same process application mode as ion exchangers, it is essential to review the situation in the market of ion exchange resins.

The market facts concerning ion exchange resins which have grown into a commodity product with a multi-billion dollar sales volume – are well concealed in the overall sales of multinationals that rule the field.

Ionex Sales Volume

Ion exchange resins are used in all industrialized countries. Major production facilities exist in the USA., Japan, Russia, France, Italy, Germany, and the United Kingdom. In addition, plants in Canada, India, South Korea, China, Brazil, Mexico, and several Eastern European countries manufacture ion exchange resins for domestic consumption. In developing nations, tariff regulations frequently encourage local functionalization of imported copolymers to provide ion exchange resins.

World-wide production of synthetic ion exchange resins probably exceeds $1.5 \times 10^5 \text{ m}^3$. In deionization and water softening applications, ion exchangers can be considered commodity chemicals because of the characteristic excess production capacity, limited market growth, and intense competition. However, resins used in smaller markets, e.g. chemical processing, sugar refining, pharmaceuticals, hydrometallurgy, catalysis, and wastewater treatment, are classified more as specialty chemicals.

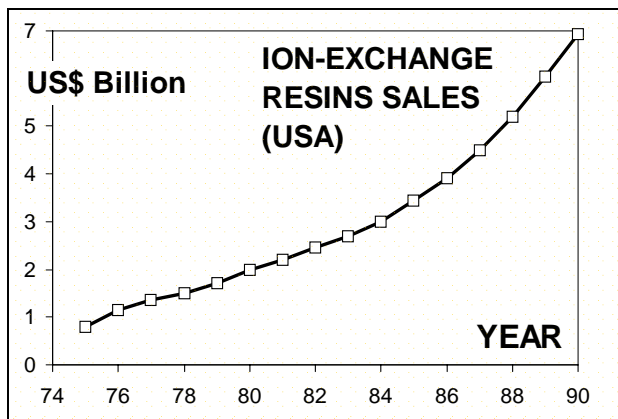
It has been extremely difficult, if not impossible, to find reliable quantitative estimates of the ion-exchange resin market. This is probably due to all the factors mentioned above and the market figures for ionex resins are hidden in the overall commodity production data released by the few transnational corporations involved. Correspondingly, the most diligent searching yielded only cursory information.

Recent Market Development

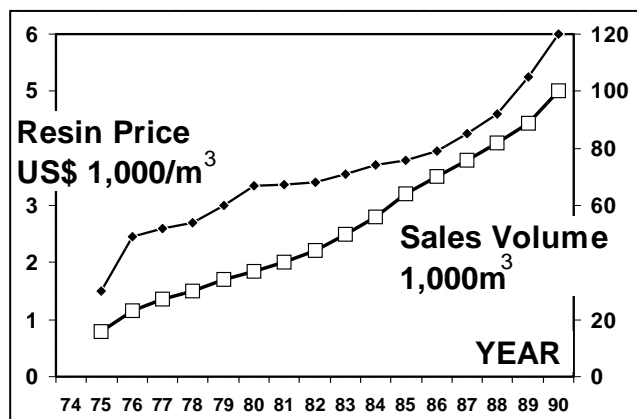
Small quantities (<15% of the market) of ionex resins are imported into the U.S. primarily because of lower prices; U.S. pricing and sales since 1975 are reflected in the Figures below.

A dramatic effect of oil price instability on resin prices has been seen already early, e.g. 1973 embargo, as styrene pricing is directly affected by the price of benzene from which it is made. Resin availability was severely curtailed then and prices rose correspondingly. The latter half of the 70s was characterized by a dollar value increase which resulted from a combination of inflationary pressures and real volume growth. The resin production volume growth partly resulted from the increased need to process poorer quality water, the resurgence of uranium processing industry and the additional use of ion exchange systems for sugar processing. Ion exchange resin sales have experienced an increased growth rate in dollar value in the early eighties, resulting still partly from inflationary effects. However, as the inflationary pressures eased off in the late 80s, the sales continued even stronger due to increasing market demands and broadening applications of ion exchange technology, particularly in the specialty chemicals domain. Obvious enormous strength of the market is in perceived applications of "clean-up" technologies due to the increasing environmental concerns.

ION EXCHANGE RESINS SALES (USA):



ION EXCHANGE RESINS MARKET (USA):



Ionex Market Volume

The total ion exchange resin sales volume in the US alone doubled from \$2.5 billion/y in 1980 to \$4.8 billion/y in 1986. These figures, reflected in the preceding diagram, indicate a strongly growing market. The main component responsible for this growth strength is the *speciality* component of the ion exchange business. The market for ion exchangers in post-communist countries is estimated to be about equal to that in the United States (in dollar value). It has been estimated that the latest total value of ion exchange resins sales world-wide (in the US dollar equivalent) amount to more than \$16.5 billion per year.

Projecting these total ion exchange sales figures into the "speciality" fraction of the ion exchange resin market represented by the non-commodity resins which do not exceed the 25% share of the total, the world sales volume for this category of ionex resin products has been estimated at approximately \$4.2 billion per year world-wide, with the North American share at \$1.6 billion per year as of the latest.

Ionex Market Limits

Approximately 75% of the resins sold in the United States go to home and industrial water pre-treatment with the balance divided between chemical processing, metal recovery, effluent and wastewater treatment and small finer specialty applications. A requirement for a competitive ion exchange material is such that it be available at such a price that its use in appropriate equipment is economically favorable over competing processes, e.g. distillation, crystallization, dialysis, reverse osmosis, electro dialysis, solvent extraction, etc. The market price of ion exchange resins is such that it seriously limits the feasibility of the process in truly huge area of wastewater treatment applications which is becoming increasingly more prominent due to mounting environmental pressures. It seems that this expanding market will belong to alternative technologies which can offer similar service at a fraction of the ion-exchange price.

Biosorbent Market Opportunity

The new discoveries and the pioneering R&D work on the new biosorbent materials have established their extraordinary potential in binding heavy metals. The major application and market opportunity for the new biosorbent materials is correspondingly seen in the field of detoxification of metal-bearing industrial effluents & metal recovery. Currently, these applications represent approximately 15% of the established ion exchange market. On a world-wide basis this represents a 15% fraction of the \$16.5 billion per year sales which is \$2.483 or approximately \$2.5 billion/year. Transposed to the North American fraction of about 1/3 of the world figure, this signifies current sales of approximately \$800 million/year worth of metal-binding ion exchange resins. A very conservative estimate could expect the new and cheaper biosorbents to penetrate that market to the level of at least 15%. Even with no expansion of the market, this represents a currently existing market opportunity amounting to \$120 million/year in North America alone.

Expanding Markets

The market share of biosorbents is expected to grow exponentially with their price edge which will tend to open new markets inaccessible to ion exchange resins due to their high costs: Current ionex resin price: \$50-70/kg

Estimated biosorbent cost: \$ 3-7/kg

With the application mode of the two "active" products being practically identical, the conspicuously lower price of biosorbents signifies a qualitative change in the market structure which is likely to open up with applications which were not feasible for conventional ion exchange resins. Nowhere else is this case as apparent as in the field of environmental applications. Large volumes of metal-bearing wastewaters make more expensive conventional treatment technologies prohibitive. As a result, these newly opening market opportunities for biosorbent products will not be accessible to ion exchangers. At the same time, the environmental regulatory pressures will obviously not subside, ever. Increasing strong trends toward preservation of the environment and recovery of resources provide a powerful stimulus for ever widening scope of biosorbent technology applications. The situation has been changing and the new market opportunities for the clean-up technologies being opened are truly enormous.

Market Opportunity for BV SORBEX, Inc.

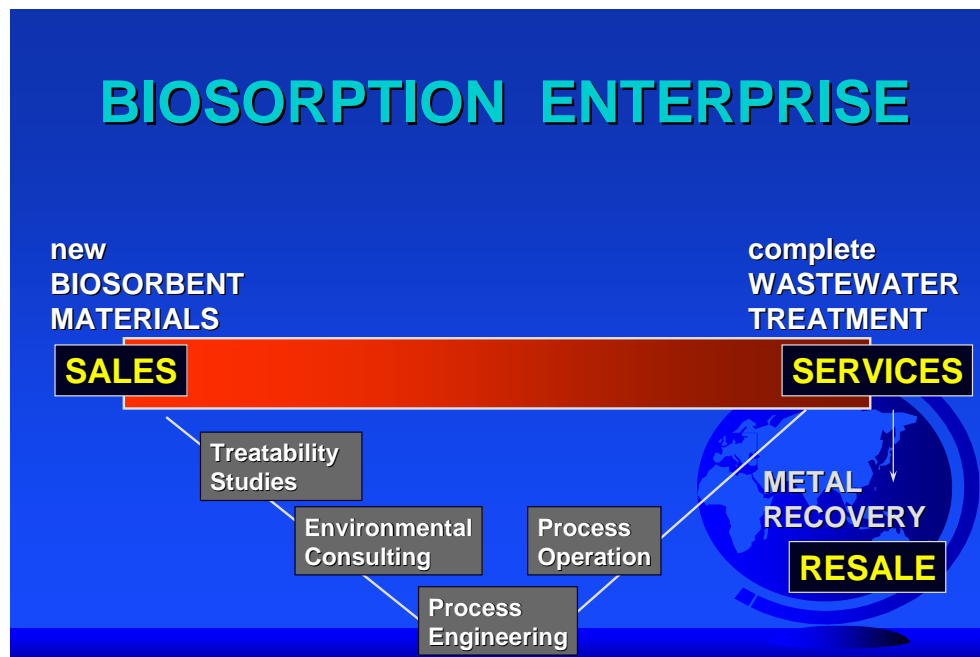
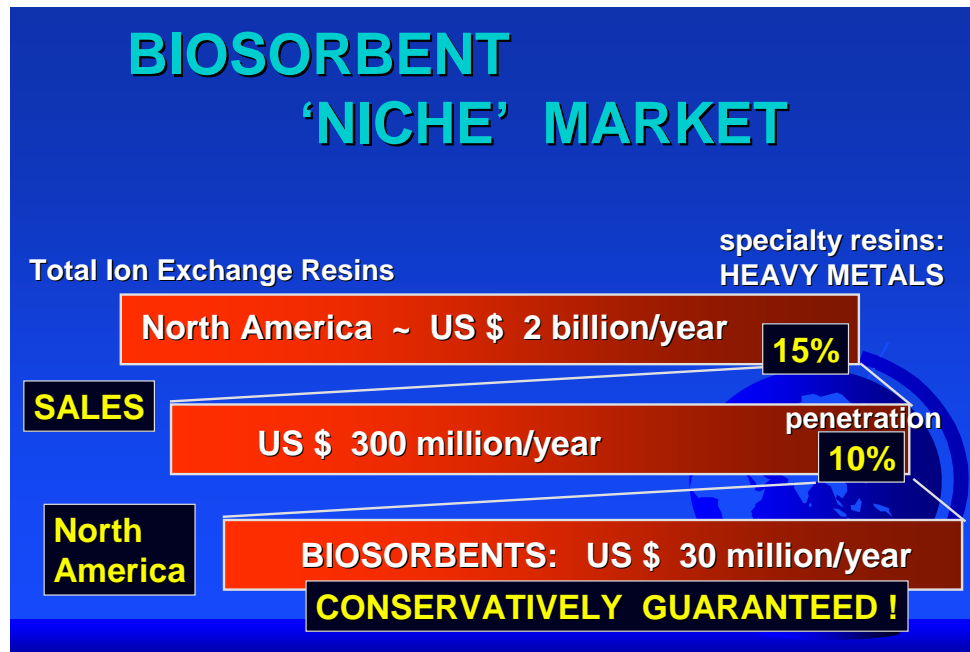
Products:

Further development of BV SORBEX, Inc. is backed by its current technological and know-how advantage. Provided that the corporate start-up phase and further growth of BV Sorbex, Inc. will be well managed, it can be assumed that it will developed into the leading enterprise in the new technological field. It would not then be unreasonable to consider that its market share could be secured in the vicinity of 25% of the total market for biosorbents. This translates to a very conservatively estimated currently existing market opportunity in biosorbent *products* for BV SORBEX, Inc. of approximately **\$28 million per year** in North America alone (see the chart on the next page).

Services:

The above product market share does not include the engineering service market component which is logically part of the BV SORBEX, Inc. business plan. In order for a new family of biosorbent products to find its best uses in well designed and efficiently operating applications, a host of consulting and engineering services has to precede and accompany the operation of actual effluent treatment plants. For best results, client-based treatability studies have to be carried out and product application schemes designed. The actual operation of the biosorption plants may also be contracted out by the client to the Company which may also be looking after the recovery of the metals removed from the solutions. Appropriate engineering back-up of the biosorbent products is essential. Realistically estimated *service* market currently exists in the order of **additional \$60 million/y** for North American biosorption applications alone.

The immediate initial market share of the biosorbent venture can be estimated from anticipated penetration of *existing* proven ion exchange resin markets :



Biosorption enterprise is intended to be *broader* than just selling biosorbents – selling equipment too. In addition, the spectrum of *services* from treatability studies to the entire process operation gives BV SORBEX, Inc. a wider, more dynamic and more flexible business base.