ments from a number of fishery scientists. Therefore, *Current Science* must first be complimented for its greater visibility among fishery scientists of India. Indian fishery scientists must also be complimented for the accelerated scientific publications at the rate of 460/annum in fishery science[3], in comparison to the annual output of 50 publications on the whole of aquatic biology during the 80s[1]. Representations made by scientists like P. K. Krishnakumar[4], that Jayashree and Arunachalam[3] should have used more keywords than 'fishes' and 'aquaculture' and 'India' alone are not important. Aquisap *et al.*[1] also pointed out that the expected annual citation rate for the publications of Asian aquatic biology was 1.29 but the observed rate was 0.78 only. Unfortunately, the visibility and citation rate for publications on fishery science by Indians have continued to remain low.

Jayashree and Arunachalam[3] should be complimented for showing contributions made by different Indian institutions, both government and university. A fact that merits consideration by Jayashree and Arunachalam[3] is that they have analysed publications on fishery science by Indians only from the point of view of Garfield[5]; for each scientific publication, two kinds of impact may have to be considered, especially for food production sectors, which are critically important for developing countries like India. The point raised by E. Vivekanandan[6] on the impact made by Indian research publications in fishery science on 'productivity' is significant and it is likely that Jayashree and Arunachalam[3] may consider and modify Garfield's[5] concept to make a scientometric analysis of research publications suitable for countries like India.

An analysis made by Ponniah[7] shows that in pollution studies relevant to fishery science, 47% of publications selected tilapia as a model species. Unfortunately, rohu has received attention by only 0.3% publications. Pollution research on rohu will be more relevant to India. An analysis of this kind could have proved a constructive suggestion to fishery scientists of India.

Perhaps Jayashree and Arunachalam[3] will have an occasion to discuss with other fisheries experts in the ensuing national seminar on 'Sustainable Fisheries for Nutritional Security' to be held at Chennai during December 2000 and will draw such conclusions, which may help the Indian fishery scientists to make a greater impact on scientific and economic development of India.

1. Aquisap, A. C., Carigom, M. A., Carino, P. B., Castrillo, V. M. J., Gayanilo, F. C. Jr., Guzman, M. E. S., Janagap, C. C., Maclean, J. L., Panly, D., Tech, E. T. and Temprosa, R. M., Asian Fisheries Society, Manila, Philippines, 1991, pp. 1–45.
2. Pandian, T. J., Proc. Natl. Seminar, INSA, 1992, pp. 18–27.
3. Jayasree, B. and Arunachalam, S., *Curr. Sci.*, 2000, **79**, 613–620.
4. Krishnakumar, P. K., pers. commun.
5. Garfield, E., *Curr. Contents*, 1979, **46**, 313–318.
6. Vivekanandan, E., *Curr. Sci.*, (in press).
7. Ponniah, A. G., in Proc. Sustainable Fisheries for Nutritional Security (ed. Pandian, T. J.), National Academy of Agricultural Sciences, New Delhi, 2000 (in press).

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Drug delivery – Today's scenario and opportunities for Indian pharmaceutical industry

In India, apart from the software industry, the pharmaceutical sector is the only one showing a constant growth of 15%, one of the highest in the world, in the last several years. At US$ 3.1 billion, the Indian pharmaceutical market is the fourth largest in the developing world and is expected to increase its annual growth from 15 to 18%, i.e. more than twice the expected growth of the world pharmaceutical industry[1]. Surprisingly, Indian per capita annual consumption of drugs of Rs 125 is one of the lowest in the world. With the implementation of TRIPS agreement which will allow the protection of product patents in India, the total scenario is going to change soon. This would demand the Indian pharmaceutical industry to spend more on R&D and to compete with the international market. Worldwide the pharmaceutical industry spends between 15 and 20% of its revenue on research compared to 1.8% by the Indian industry[1]. Research in the development of drugs has generally two major aspects, viz. (i) discovery of a new drug molecule (new chemical entity, NCE), and (ii) invention of new formulations of drugs with higher therapeutic index. The latter would minimize the unnecessary drug loss and unwanted side effects. In a recent editorial in *Current Science* it has been mentioned that discovery of new drugs involves huge expenditure to the tune of about Rs 2000 crores[2]. As a matter of fact, in the last twenty years no breakthrough drug molecule has been discovered anywhere in the world. What people have done is to synthesize a molecule by altering its structure to have enhanced therapeutic value[3]. In India during 1956 to 1995, a period of nearly forty years, only 14 drugs have been developed indigenously[4]. There is an increasing gap in drug research in the Indian pharmaceutical industry from the world scenario.

In the world scenario, drug delivery is an expanding industry based on hundreds of companies providing expertise and innovative technologies for improved delivery systems. Enhanced delivery leads to superior performance characteristics of the products. The blockbuster drugs whose life span in the market has been exhausted, can be resurrected by reformulating the drugs through novel delivery systems. At the same time the effective patent protection can also be enhanced. In India, pharmaceutical companies are facing a new challenge of generic competition for a particular drug whose patent life span has expired. The difficulty would increase enormously in the near future

because the patent life span of many drugs is going to expire and in India product patent is going to be effective from the year 2005. This is a major issue the pharmaceutical companies have to take into account as more than 35 billion US dollars worth products will be facing generic substitution over the next fifteen years. This is a key restraint in terms of revenue generation for the pharmaceutical companies. According to the *Financial Times* management report[5], the size of the worldwide drug delivery market in 1999 was about 24 billion US dollars, which is expected to rise up to 78 billion US dollars in the year 2005. Surprisingly the share of India is less than 0.1% (ref. 6).

It seems, therefore, clear that drug delivery sector of the Indian pharmaceutical industry has not yet taken off. There is no lack of innovative research capability in the country. However, in recent years there have been signs that the academia–industry chasm has been growing.

Why is the drug delivery technology important to the Indian pharmaceutical industry? Some of the most important reasons are: (i) drug delivery formulations involve low cost research compared to that for the discovery of a new molecule, (ii) minimizing drug use would significantly reduce the effective cost of the drug, which would give financial relief to the patients, (iii) delivery systems increase commercial opportunity by distinguishing a drug from competitive threats posed by 'me too' drugs, and (iv) novel means of delivery can allow branded drugs to be rescued from the abyss of generic competition. Moreover, delivery systems maximize therapeutic benefits through targeted and controlled release of drugs and offer alternative routes of delivery, which protect the drug from enzymatic degradation and unnecessary toxic hazards.

It terms of route of delivery of a large number of biotechnology products, a large number of these are delivered via injection. This presents an opportunity for various emerging routes of drug delivery to gain acceptance in the market place.

There is another element, namely the 'life cycle management' of the drug. The global market for pharmaceuticals is currently valued at approximately 295 billion US dollars and is expected to be doubled by the year 2002. In Europe and America this has driven the industry to repackage the same drug with novel delivery technologies in order to extend the patent life. An example is Amphotericin B, which is a water-insoluble antifungal drug with poor absorption and poor tissue distribution. Fungizone is a mixture of this drug with sodium cholate and this mixture is water-soluble. This preparation is available in the Indian market as generic drug. Nexter in USA has developed a liposomal formulation with less toxicity and with better therapeutic efficacy as a non-generic drug. Because of certain limitations of liposomal formulations, a better formulation with much lower toxicity and higher fungal uptake has recently been formulated by our laboratory and Indian product and process patents (WTO patents) have been filed. Similarly, several non-steroidal anti-inflammatory drugs like ketorolac, indomethicin and nimesulide are all generic drugs and have free competition in the market. Recently, we have developed improved ocular delivery system formulations using mucoadhesive, temperature-sensitive nanoparticles of size less than 50 nm diameter and encapsulating these drugs which have much higher bioavailability of drugs on the cornea surface. The patent for taxol, expired in December 1997. An Indian company has recently filed a patent in several countries on improved formulation of taxol encapsulated in nanoparticles (developed by our group), which has much higher therapeutic index than taxol dissolved in lipidol oil. There are many such examples. These improved formulations help one to have enhanced patent life of the drugs and thereby enhanced market penetration.

Liposomal and nanoparticles formulation technologies are coming up in a big way in the drug delivery market. These particles can be tailored-made so far as their size and surface properties are concerned. Both liposomes and nanoparticles of extremely small size (< 100 nm diameter and comparable to those of viruses) can be prepared. Their surface hydrophobicity/hydrophilicity can be modulated as per requirements. Targetable ligands and antibodies can be chemically and physically attached to these particles. The core of these particles can be made hydrophobic as well as hydrophilic according to the nature of the drug to be entrapped. Nanoparticles of intelligent polymers can also be made. These particles are now being used in highly specialized areas like gene delivery, delivery in brain, tumour targeting, oral vaccine formulations and other areas. These formulations would result in a barrier for generic competition by 'raising the technology barrier' to levels with which generic cannot compete. It is time that our pharmaceutical industry realizes the potential of this expanding area of drug research and development.

1. 32nd Annual Report '97–'98, Org. of Pharmaceutical Producers of India.
2. Balaram, P., *Curr. Sci.*, 2000, **78**, 937.
3. Sangeeta, V., *Industrial Economist*, 15–29 April 2000, pp. 24–28.
4. Shaikh, S., *Indian Pharmaceutical Market, Drug and Market Development*, 1 April 1999, **10**.
5. The *Financial Times* Management Report, 1999.
6. 3rd Annual Conference on Drug Delivery Systems, 24–25 May 1999, Washington DC.

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