8. Fuglsang, A., *Biochem. Biophys. Res. Commun*., 2005, **327**, 1–3.
9. Fuglsang, A., *Biochem. Biophys. Res. Commun*., 2004, **317**, 957–964.
10. Fuglsang, A., *Gene*, 2003, **320**, 185–190.
11. Fuglsang, A., *Genetics*, 2006, **172**, 1301–1307.
12. Verma, S. K., Das, D., Satapathy, S. S., Buragohain, A. K. and Ray, S. K., *Curr. Sci.*, 2005, **89**, 374–384.
13. Prabhu, V. V., *Nucleic Acid Res*., 1993, **21**, 2797–2800.

ACKNOWLEDGEMENTS. We thank the Department of Biotechnology, New Delhi for providing funds under the twining project in bioinformatics. We also thank Dr T. C. Gosh (Bose Institute, Kolkata) for valuable discussions and Ms Ruksana Aziz (Tezpur University) for useful comments.

SIDDHARTHA SANKAR SATAPATHY[1]
SUVENDRA KUMAR RAY[2,*]

[1]*Department of Computer Science and Engineering, and*
[2]*Department of Molecular Biology and Biotechnology,*
Tezpur University, Napaam,
Tezpur 784 028, India
**e-mail: suven@tezu.ernet.in*

Pharmaceutical residues in India: impact on aquatic environment

India is the world's third largest manufacturer of pharmaceuticals, with exports to over 65 countries[1]. By 2020, the country would be ranked in top 10 largest pharmaceutical markets in the world[2]. Typically, pharmaceutical drugs (anti-inflammatory, antiepileptic, lipid lowering agents, β-blockers, antibiotics, diuretics–antihypertensive, androgens, estrogens, etc.) are widely produced and prescribed for human and veterinary, agriculture and aquaculture purposes for protection against various diseases and further to improve human health[3,4]. The large-scale production and extensive use of these compounds as well as their disposal from medical centres and discharge of domestic wastewaters has resulted in environmental contamination[5,6]. These compounds are not completely degraded in the environment and as a result a number of pharmaceuticals are being reported. Globally, in recent times, the presence of these active ingredients and their metabolites has been detected[6–8] in various segments of the environment such as treated and untreated sewage effluents, groundwater, surface water, drinking water, lakes, rivers, reservoirs, estuaries and seas, at concentrations ranging from ng l^{-1} to $\mu g\ l^{-1}$. Such low concentrations also cause public health problems[9–11] (Figure 1). Therefore, pharmaceutical contamination is an emerging concern worldwide and called as emerging pollutants by many scientists.

Pharmaceutical drugs contaminating in the environment have been reported in various countries like USA, UK, Germany, France, Spain, Canada, Australia, Ireland, Belgium, Switzerland, Italy, China and South Korea. However, there are no sufficient data on the occurrence and fate of pharmaceutical drugs in India[12]. There are many possibilities for the occurrence of pharmaceuticals in the water sources of India. Further, because of a large population and with many hospitals located in big cities, pharmaceutical drugs can easily be discharged to the nearby water system daily. So far, very few studies have been done in this regard, even though India has been increasingly producing and consuming pharmaceutical drugs. For instance, Larsson *et al.*[13] have reported elevated concentrations of pharmaceutical drugs such as ciprofloxacin, losartan, cetirizine, metoprolol, enrofloxacin, citalpram, norfloxacin, lomefloxacin, enoxacin, ofloxacin and ranitidin (range between 90 and 31,000 $\mu g\ l^{-1}$) in the effluent of sewage treatment plant in Patancheru Enviro Tech Ltd (PETL), Patancheru, Hyderabad, India. In addition, Fick *et al.*[14] reported that ciprofloxacin, enoxacin, cetirizine, terbinafine and citalopram were detected at more than 1 mg l^{-1} in several wells close to PETL. Very high concentrations of ciprofloxacin (up to 6.5 mg/l), cetirizine (up to 1.2 mg/l), norfloxacin (up to 0.52 mg/l) and enoxacin (up to 0.16 mg/l) were also detected in the two lakes in the proximity of PETL. Diwan *et al.*[15] quantified high concentrations of ciprofloxacin (218–236 $\mu g\ l^{-1}$), norfloxacin (6.4–22.8 $\mu g\ l^{-1}$), levofloxacin (5–8.8 $\mu g\ l^{-1}$) and ofloxacin (4.5–7.5 $\mu g\ l^{-1}$) in hospital wastewaters in Ujjain, India. Ramaswamy *et al.*[16] reported carbamazepine (antiepileptic drug) at 28.3 ng l^{-1} in the Kaveri, a major South Indian river. Recently, the occurrence of non-steroidal anti-inflammatory drugs such as diclofenac, ketoprofen, naproxen, ibuprofen, and acetylsalicylic acid was examined in Kaveri, Vellar, and Tamiraparani rivers in southern India[12]. Research has shown that the environmentally relevant concentrations of pharmaceutical drugs cause toxicological health impacts on various aquatic organisms. Therefore, occurrence and toxicity of pharmaceuticals and their derivatives in the aquatic environment are now a growing concern[5,16].

The rapid growth of pharmaceutical industry in India has posed an elevated risk of environmental contamination with residual pharmaceuticals. However, only a limited number of studies can be found

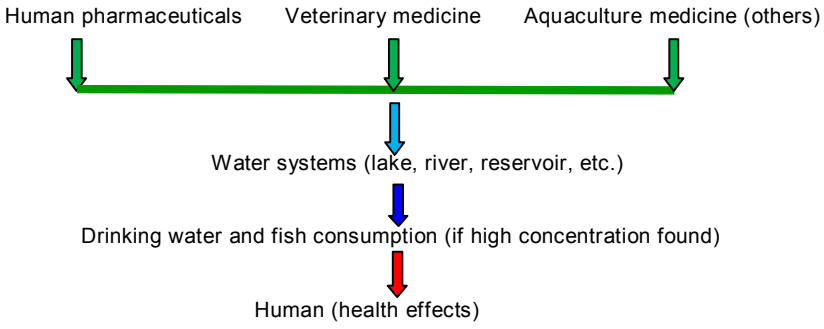

Figure 1. Major source and route of the pharmaceutical drugs to humans.

regarding the status of pharmaceutical contamination in India[17]. These emerging environmental pollutants in aquatic environment may affect the biological systems of terrestrial and aquatic ecosystems[18,19]. Further, it may act on molecules, cells and organs and pose a serious threat to aquatic organisms through unexpected modes of action[6,20]. Therefore, their potential effects on all segments of aquatic systems, fauna and flora warrant the biomonitoring of these emerging environmental contaminants in India.

More importantly, studies on the potential adverse ecological impacts of pharmaceutical drugs and their residues on the physiology of aquatic organisms are scarce in India[21]. For instance, Malarvizhi *et al.*[22] found significant alterations on enzymes in gill, liver and muscle of a freshwater fish, *Cyprinus carpio* exposed to Carbamazepine. Saravanan and co-workers[4,10,11,21] reported toxicological effects of clofibric acid (lipid regulating pro-drug), diclofenac (non-steroidal anti-inflammatory drug) and ibuprofen (analgesic, antipyretic and anti-inflammatory) in an Indian major carp, *Cirrhinus mrigala* and *C. carpio*. Ambili *et al.*[23] observed significant alterations on hematological and enzymological responses of an Indian major carp *Labeo rohita* exposed to oxytetracycline (antibiotic). Oaks *et al.*[24] found dramatic decrease in vulture (*Gyps* sp.) populations in the Indian subcontinent due to diclofenac toxicity. Thus, detailed and targeted investigations are required to study the sources, pathways and fate of the pharmaceutical drugs[17].

To remove these harmful pharmaceuticals from wastewater many scientific innovations are being implemented throughout the world. Such facilities are scarce in India and they need to be developed for a healthy environment. Big cities such as Delhi, Mumbai, Kolkata and Chennai may witness health impacts in near future due to pharmaceutical drugs and their residues. Because of continuous discharge of pharmaceuticals higher concentrations of their residues may be expected in surface water and groundwater. Hence, extensive research activities are needed to monitor the human pharmaceutical drugs in various segments of aquatic environments and on non-target organisms for better understanding of the toxicological end-point of pharmaceutical drugs.

1. Gopakumar, K. M. and Santhosh, M. R., *Third World Resurgence*, 2012, **259**, 9–14.
2. PricewaterhouseCoopers, http://www.pwc.in/assets/pdfs/pharma/The_changing_dynamics_of_pharma_outsourcing_in_Asia.pdf
3. Cunningham, V. L., Binks, S. P. and Olson, M. J., *Regul. Toxicol. Pharmacol.*, 2009, **53**, 39–45.
4. Saravanan, M., Usha Devi, K., Malarvizhi, A. and Ramesh, M., *Environ. Toxicol. Pharmacol.*, 2012, **34**, 14–22.
5. Heberer, T., *Toxicol. Lett.*, 2002, **131**, 5–17.
6. Fent, K., Weston, A. A. and Caminada, D., *Aquat. Toxicol.*, 2006, **76**, 122–159.
7. Zuccato, E., Calamari, D., Natangelo, M. and Fanelli, R., *Lancet*, 2000, **355**, 1789–1790.
8. Zhang, Y., Geisen, S. U. and Cal, C., *Chemosphere*, 2008, **73**, 1151–1161.
9. Li, Z. H., Velisek, J., Zlabek, V., Grabic, R., Machova, J., Kolarova, J. and Randak, T., *Chem. Biol. Interact.*, 2010, **183**, 98–104.
10. Saravanan, M. and Ramesh, M., *Chemosphere*, 2013, **93**, 388–396.
11. Saravanan, M., Ramesh, M. and Petkam, R., *Fish Physiol. Biochem.*, 2013, **39**, 1431–1440.
12. Shanmugam, G., Sampath, S., Selvaraj, K. K., Larsson, D. G. J. and Ramaswamy, B. R., *Environ. Sci. Pollut. Res.*, 2014, **21**, 921–931.
13. Larsson, D. G. J., Pedro, C. and Paxeus, N., *J. Hazard. Mater.*, 2007, **53**, 161–163.
14. Fick, J., Soderstrom, H., Lindberg, R. H., Phan, C., Tysklind, M. and Larsson, D. G. J., *Environ. Toxicol. Chem.*, 2009, **28**, 2522–2527.
15. Diwan, V. *et al.*, *BMC Public Health*, 2010, **10**, 414–422.
16. Ramaswamy, B. R., Shanmugam, G., Velu, G., Rengarajan, B. and Larsson, D. G. J., *J. Hazard. Mater.*, 2011, **186**, 1586–1593.
17. Rehman, M. S. U., Rashid, M., Ashfaq, M., Saif, A., Ahmad, N. and Han, J.-I., *Chemosphere*, 2013; (in press), DOI: 10.1016/j.chemosphere.2013.02.036.
18. Kummerer, K., *Pharmaceuticals in the Environment. Sources. Fate, Effects and Risks*, Springer-Verlag, Berlin, 2001.
19. Zuccato, E. *et al.*, *Environ. Sci. Pollut. Res.*, 2006, **13**, 15–21.
20. van den Brandhof, E. J. and Montforts, M., *Ecotoxicol. Environ. Saf.*, 2010, **73**, 1862–1866.
21. Saravanan, M., Karthika, S., Malarvizhi, A. and Ramesh, M., *J. Hazard. Mater.*, 2011, **195**, 188–194.
22. Malarvizhi, A., Kavitha, C., Saravanan, M. and Ramesh, M., *J. King Saud Univ. Sci.*, 2012, **24**, 179–186.
23. Ambili, T. R., Saravanan, M., Ramesh, M., Abhijith, D. B. and Poopal, R. K., *Arch. Environ. Contam. Toxicol.*, 2013, **64**, 494–503.
24. Oaks, J. L. *et al.*, *Nature*, 2004, **427**, 630–633.

ACKNOWLEDGEMENTS. This work has been supported by Prof. Jang-Hyun Hur (Division of Biological Environment, College of Agriculture and Life Science, Kangwon National University, Republic of Korea). I thank Prof. M. Ramesh (Department of Zoology, School of Life Sciences, Bharathiar University, Coimbatore) and Prof. R. Babu Rajendran (Department of Environmental Biotechnology, School of Environmental Sciences, Bharathidasan University, Tiruchirapalli) for their valuable comments and suggestions. I also thank the Council of Scientific and Industrial Research, New Delhi, for awarding the Senior Research Fellowship (09/472(0141)/2009-EMR-1).

MANOHARAN SARAVANAN

Bio-Regulatory Chemistry Lab,
Department of Biological Environment,
College of Agriculture and Life Sciences,
Kangwon National University,
Chuncheon 200-701, Republic of Korea
e-mail: msktox@gmail.com

Sun protection factor: science or advertising?

The sun has both good and bad effects on human beings. It provides warmth and light which are critical to human physical and psychological well-being. From health point of view, the sun provides support through vitamin D synthesis, kills pathogens, phototherapy, etc.[1]. The electromagnetic spectrum emitted by the sun contains 5% of UV radiations. It is essential to prevent human skin from the deleterious effects of such radiations. There are a number of ways to do so – Sun avoidance, wearing protective clothing, hats, glasses, applying sunscreen and systemic photoprotection[2]. A sunscreen