summer for agricultural as well as for domestic purposes.

No doubt, their assumptions were very close to being correct, but unfortunately they could not come to the root cause, specially in the case of the problem in urban areas. The authors believe that if the municipal water supply would have been sufficient to meet the public need, the general public would not have been forced into using difficult and expensive independent water pumping systems involving jet pumps or submersible water pumps. Domestic independent water pumping systems promote wastage of water. Thus, if the concerned authorities would have improved the municipal water supply systems in time, such a problem would not have arisen.

Likewise, in the case of rural areas, traditional system of flood irrigation is followed, in which large amount of ground water is wasted through evaporation, leaching and surface flow. Water leaching from agricultural farms is harmful. Such water carries a high concentration of chemicals, especially fertilizers and pesticides, which pollute the groundwater pool. Various alternative modern systems of irrigation such as furrow, surface drip, subsurface drip, sprinkler, etc. are available but their correlation and suitability with respect to the crop, crop cycle, climate and other agro-economic factors need to be wisely explored.

Recently, the Government of India has recommended installation of groundwater recharging units at the domestic level. We feel that it is important for the authorities to gain scientific knowledge of artificial recharging in order to adequately protect the groundwater aquifers. There are certain grounds, which should be analysed and reviewed before taking the decision of artificial recharging, such as – quality of source water available for recharging; underground storage space available; transmission characteristics; best possible applicable method (injection/infiltration), cost of construction, regulation and the recurring charges, public perception, maintenance problem, etc.[5].

One must also not fail to analyse possible disadvantages, which may appear in some of the following ways. The recharging units may fall to disrepair and ultimately become sources of groundwater contamination[5]. Recharge can degrade the aquifers unless quality control of the injected water is adequate. Run-off water containing high organic matter may result in microbial growth in aquifers. Further, chemical reactions may get initiated by mixing of chemically dissimilar water[6]. High dissolved oxygen in rainwater may dissolve metalloids bound in rocks and release them in the aquifers.

According to a report on the effect of artificial recharge on water quality in the aquifers, elevation in the level of chloride, arsenic, total coliform bacteria and atrazine, a herbicide, have been reported[7], though, the source water used was treated to reduce turbidity and to remove organic compounds using powder activated carbon.

There are several artificial recharge techniques in use in Latin America and the Caribbean, including infiltration basin, water traps, cut waters, surface runoff drainage wells, septic tanks, effluent disposal wells, sinkholes, etc. But the only process imposed on the urban society in India is the deep injection borewells. By such a decision the state is free and the problems now lie at the doorsteps of owners of borewells. In the Indian perspective, where it is hardly possible to use filters for drinking water, is it possible for each and every family to allow rainwater to occupy the aquifers after proper treatment, as water injected through this process should be potable water treated to drinking water standards[5]?

We respect the wisdom of people in advocating artificial recharge but we are of the view that for surface recharge, rainwater need not be treated. If we go through the last two to four decade maps of any city, we may find a large number of water bodies that have now been encroached upon. If they are restored, they may solve the problem.

The decision of recharging the ground water is not a simple trial and error experiment. It is an experiment with nature and nature takes revenge in the form of 'ecological backlashes'. We need to be awake today or we shall not be able to awake tomorrow.

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The Indo-US nuclear 'deal'

I read with great interest Srinivasan's article[1] on the Indo-US nuclear 'deal'. It provided valuable background information. However, certain claims made for a new process in an article in a recent issue of the *Scientific American*[2] if true, can upset all considerations that must have gone into arriving at the 'deal', a prime one being that India has no good sources of uranium.

The process is said not only to allow one to get more energy from a given quantity of fissile material but also to take care of long-term radioactive waste! Briefly stated in simplified manner, new metal fuel rods can be made from mixtures of uranium and actinides recovered from materials produced by present-day reactors, regarded as 'waste', through electrorefining and pyrometallurgy. Solutions of salts of metal mixtures recovered from such wastes (by reduction of oxides from thermal reactors and chopped up metallic fuel elements from fast breeders) are subjected to electrolysis. The partly separated metal mixture deposited at the cathode, mostly free from cadmium (and, presumably, other fission products that can absorb neutrons), is further subjected to high-temperature purification and cast into new fuel rods suitable for bombardment by fast neutrons; I presume these are moderated to get optimum nuclear 'cross-section'. However, fast neutron reactors cannot use water as a coolant and must depend on liquid metal (sodium already in such use as a heat transfer agent). The authors have further claimed such advantages as: no uranium enrichment is needed ever, waste forms only 1% of what is obtained now, the waste need not be kept under secure storage for 10,000 years as of now but only for 500 years, actinides, recovered mixed with uranium, will not be of weapons-grade and so on.

I believe that a cycle similar to that described for uranium can be operated with thorium of which, as everybody knows, we have abundant sources. I hold on to the hope that our atomic scientists and engineers are already at work in this connection. If the technology is mastered, India need not really depend on the US or the Nuclear Suppliers Group for uranium supplies and all its energy needs can be met for a long time to come. India may still have to depend on instrumentation and control systems on external suppliers, a weak point.

Srinivasan has described, clearly and with all the authority he commands, the pros and cons of the Indo-US nuclear deal. The pros say that it is a 'very good' deal provided the US Congress waives or annuls previous, specifically anti-India, legislation and India would be free to address its growing energy needs. The cons feel that the US has a deeply laid, clever plot by which it gets the means to 'finger' India's nuclear programme. Moreover, the Fissile Materials Cut-off Treaty can be used to get back for all the 'waste' and deny full use of the fuel – maybe the US knows that the fast neutron technology described in the *Scientific American* is already nearing commercial viability.

I, and your other readers I am sure, would be happy to get expert opinion.

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Reply:

I have read the correspondence from S. N. Balasubrahmanyam, commenting on my article published in *Current Science*. I have not read the article in *Scientific American*, on smarter use of nuclear waste. It is, however, clear that the authors are referring to the use of fast reactors to use uranium more efficiently than is possible in thermal neutron reactors. This argument applies in the US context because from the time of President Carter, the US suspended work on fast reactors from considerations of non-proliferation. There is a change in US perceptions now as a number of designs, under consideration in generation-IV programme, are based on use of fast reactors. Fast reactors utilize the uranium resources more efficiently and also produce new fissile material such as plutonium 239 and uranium 233. Fast reactors also burn, *in situ*, higher actinides and thus minimize the waste problem.

India's interest in fast reactors is because it opens a way of utilizing the energy potential of thorium. However substantial quantities of plutonium are required to start off the fast reactors. This plutonium can come from natural uranium heavy water reactors (such as the ones we have built and are building) or from low enriched uranium light water reactors. The need to import natural uranium arises because the total amount of uranium available in India, as of now, is not large. Our presently known ores are of low grade and price of uranium produced in India is more than five times the international price. If we depended only on our own resources of uranium, we can only have a slow growth of nuclear power capacity. Given the constraints on expanding coal based power (through CO_2 burden in the atmosphere), on gas (due to limited availability and imported LNG prices being linked to crude oil price) and on hydro electricity (due to opposition against dams because of rehabilitation and submergence questions), India needs to rely more on nuclear energy to enlarge the electrical generation capacity almost immediately.

Of course, in advocating the India–US nuclear deal, the author has stressed that India cannot go beyond the parameters of the July 2005 and March 2006 agreements. India may find any new condition, the US Congress may impose, to be unacceptable. In that case, India will proceed on its own as it has done hitherto.

While the initial fast reactors India will build, will use mixed oxide fuel (i.e. mixture of uranium oxide and plutonium oxide), a second phase would use uranium and plutonium metal alloy. The metallic fuel promises higher breeding gain (i.e. an increase in the production of new fissile material). At that stage, we shall have to use pyrochemical processing of spent fuel, possibly using molten salts. Our scientists are studying these questions actively.

On the question of burning nuclear waste, an approach India is pursuing is the use of accelerator-driven-systems (ADS) for using thorium. In this scheme, high-energy protons from an accelerator impinge a target, such as lead, releasing a lot of neutrons in what is known as a spallation reaction. These neutrons can then initiate fission in a sub-critical assembly with thorium. India may use this route as an additional route to use thorium. These systems can also burn some of the nuclear waste and thus minimize the waste management problems in the longer run. Indian scientists have been engaged in studying the ADS route also.

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