means), into biotechnology? Why is there an irresistible urge to use the prefix 'Bio' and the suffix 'Biotechnology' with every term/title?

It is really puzzling to students and staff alike, that the contents of so many theses, research papers and other publications, conferences, seminars, etc. and research projects funded by different agencies, are the same, as it was once upon a time but for the prefix Bio and the suffix Biotechnology to their titles.

It is worth noting that even for the work carried out on modern lines, some prefer to use the above prefix and suffix while others do not. And, some even prefer to publish under the domain of old parent disciplines, like physiology, biochemistry, genetics, microbiology, etc., thought their work employs all the modern techniques. On the contrary, we have people, even if they run a gel once, they feel badly offended, if they are addressed as any thing other than as a 'biotechnologist'.

Why don't we (or don't we want to) discriminate between 'a technique' and a discipline or a branch of knowledge?

For example, ELISA is used by many researchers, plant physiologists, plant breeders, etc. Because of using this technique, they do not become qualified immunologists. Radioactive techniques find use in so many disciplines. Just because, somebody has used ^{14}C in his experiments, he/she does not become a nuclear physicist.

From time to time, new techniques keep on emerging, which can be made use of by many in their respective disciplines and to solve research problems. I do not know, because of a new technique(s) why the system should allow one to destroy other professions and programmes to the ultimate detriment of the education system as a whole?

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SCIENTIFIC CORRESPONDENCE

Groundwater development in the arsenic-affected alluvial belt of West Bengal – Some questions

Hydrogeology

It is now recognized that a huge alluvial tract bound by the Bhagirathi (Ganga) river in the West, Malda district in the North and 24-Parganas in the South (eastern boundary perhaps extending into Bangladesh territory) is affected by arsenic pollution of groundwater. The western part of Bengal, i.e. west of Bhagirathi river is not reported to have been hit. Also the northern part or the sub-Himalayan areas of West Bengal, i.e. West Dinajpur and Coochbehar districts, are as yet unaffected. Is Nature angry with the people of the eastern belt? What is the significance of this selective contamination from the hydrogeological point of view (Figure 1).

The Bengal basin has four phases of depositions and erosions coinciding with four inter-glacial and glacial periods in the Quaternary time (0 to 1.6 million years). Prior to the recent deposition of Sunderban Delta and active river banks, a deposition took place some time between 25,000 and 80,000 years ago (commonly known as the younger deltaic deposits, YDD). The sediments were mainly brought by the Ganga (Belt I in Figure 1).

The major part of the western alluvial belt (Belt II in Figure 1) called the Older Deltaic Plain (ODP) developed during Quaternary time between 80,000 and 1.6 million years ago by 2 or 3 glacial–interglacial cycles with sea level fall and rise coinciding with the glacial and deglaciation phases respectively. Sea level fall (i.e. Bay of Bengal's fall) results in an erosional phase and sea level rise results in depositional aspects in the river system. These sediments were brought from the Chotanagpur plateau of Bihar by easterly flowing river systems like the Ajay–Damodar–Subarnarekha.

ODP extends into the sub-surface below the arsenic belt (YDP) and takes its proper stratigraphic position[1]. That is why perhaps deeper aquifers under the arsenic belt are as yet free from arsenic contamination.

The sediments comprising most part of the districts of West Dinajpur, Coochbehar, etc. (Belt III in Figure 1) were brought by Himalayan rivers coming from the North and therefore are different from the Ganga sediments.

Groundwater development structures

It is known that billions of litres of water have been and are being pumped out every year from this belt with the help of groundwater structures (Table 1).

Working schedule

Except during the rainy season (June to September), irrigation pumps are run for a few hours almost daily to irrigate the nearby fields. Pumping for eight hours per day is common. It has been estimated that on the average an irrigation pump runs for about 500–800 hours a year. Water supply tubewells, however, run throughout the year.

Arsenic mixing in the aquifers

In our earlier model we attempted to show how there was increased supply of oxygen to groundwater[2]. The cause of this increased supply of oxygen is due to the operation of tubewells known to cause extension of vadose zones (VZ), i.e. unsaturated air–water mixed zones (Zs) (Figure 2), during pumping, thereby supplying more oxygen/dissolved air with oxygen as an important constituent to the groundwater.

It is, therefore, expected that though arsenic-bearing bed (layer) may be found

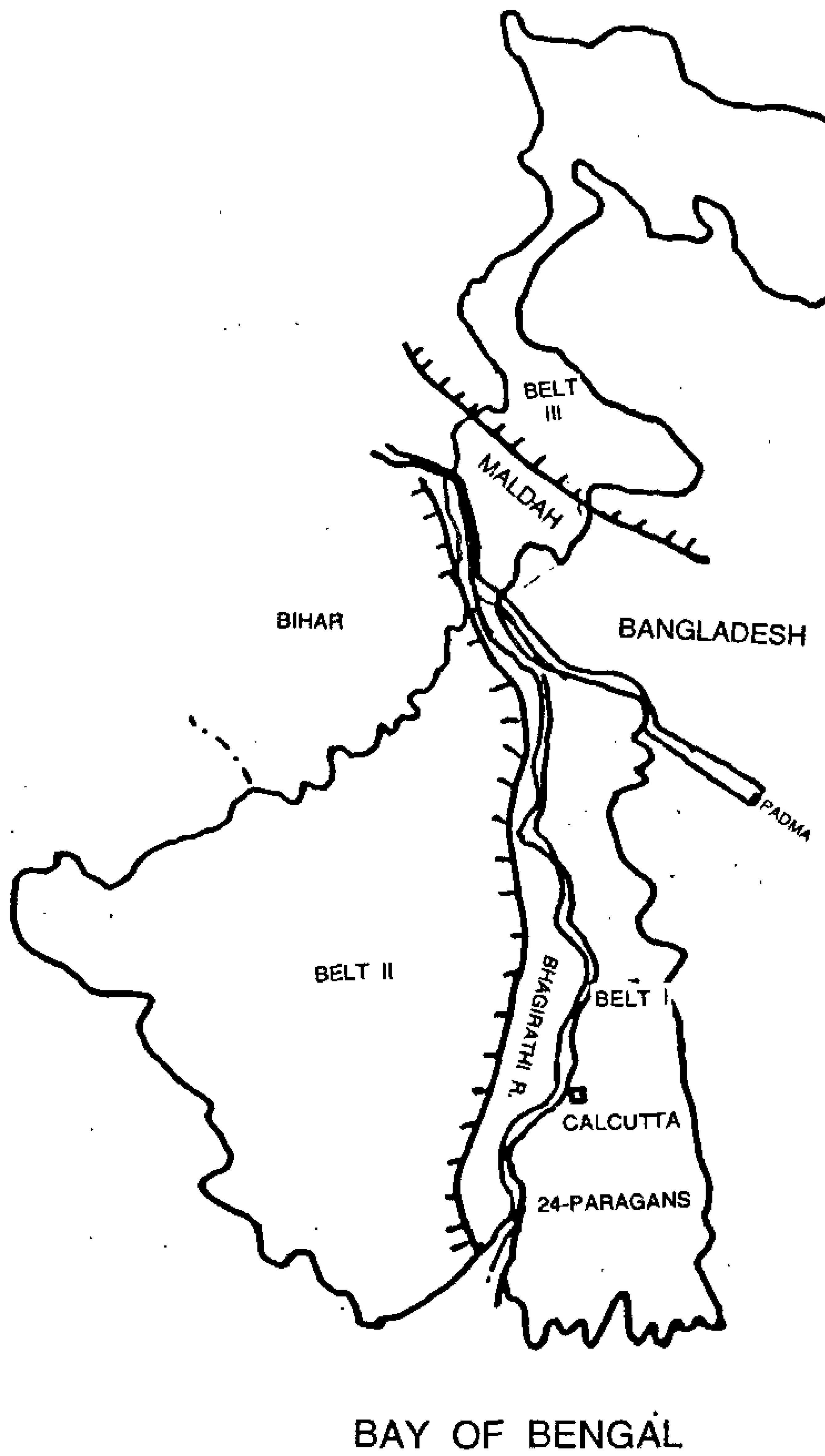

Figure 1. Map showing three broad divisions with respect to occurrence/absence of arsenic in groundwater. Belt I is the arsenic-affected division consisting of sediments brought by the Ganga; Belts II and III are arsenic-free zones consisting of sediments brought by rivers other than the Ganga.

throughout the five districts (in the eastern belt) in discontinuous forms (lenses), the release of arsenic will take place only around the areas (VZs and Zs) where increased supply of oxygen/dissolved air is available and is reacting with the arsenic-bearing formation. It is to be noted that the arsenic-bearing deposits can neither occur at a uniform depth nor can have uniform thickness.

In normal conditions groundwater movement (velocity) is very slow in the arsenic-affected tract of West Bengal owing to its flat nature (average slope is 10 cm/km). The groundwater movement is of the order of 500 cm per year in horizontal direction and still less as far as vertical movement is concerned. Vertical movement, however, is much faster in the vadose zone (VZ in Figure 2) created by annual water level fluctuation (about 4 m in VZ(1), rectangular and wide spread) and due to draw down, during pumping (up to 10 m in VZ(2), in an inverted conical form, Figure 2). What happens daily is a downward movement of water–air particles in VZ(2) zone during pumping and upward movement when the pump is stopped after a few hours.

Leaving aside this mixing mechanism, one may examine the velocity of groundwater in the vicinity of the strainer (or slotted pipe) of the tubewell deep under ground in the aquifer, when the pump is in operation (in zone Z in Figure 2). If Q is the steady state discharge of a tubewell pumping water continuously then the same Q amount of water must enter the tubewell through the strainer pores to maintain the discharge.

Therefore,

Q = velocity (V) × pore area of the strainer (A)

$A = x\%$ of $2\pi r_w h$, where r_w = radius of the strainer, h = length of strainer and $x\%$ is the percentage of open space in the strainer which in field conditions varies from 30 to 70%.

For heavy/medium duty tubewells and shallow tubewells the value of V varies from 0.01 to 0.5 cm/sec. This is several thousand times more than the convective velocity of natural groundwater (or groundwater in unexploited aquifer).

What is the velocity, a few meters away from the strainer?

Normally a velocity gradient is created around the tubewell strainer and spreads at least up to the limit of the cone of depression. This value is of the order of 250 m radius in case of heavy duty tubewell and 50 m in case of shallow tubewells. Velocity is maximum at the entrance points where $r = r_w$ and minimum (tending to zero) at the outer surface of the cylinder of influence having equivalent radius of the cone of depression.

In other words, each tubewell while in operation is acting as a stirrer (a spoon in a tea cup) for an aquifer of cylindrical volume of about 50 to 250 m radius with its height being the entire depth of the tubewell strainer (Zs in Figure 2). If the source of arsenic is located somewhere in this zone it can get mixed up with the entire volume of the tubewell's effective influence zone within a short time. Otherwise, perhaps it would have taken thousands of years for the arsenic to spread in the natural course, through dispersion–convection mechanism.

Consider a situation where thousands and thousands of tubewells are running in the arsenic-affected alluvial belt simultaneously. The predominant parameter for mixing will depend on a convection–dispersion model in which convective velocity will be overwhelming compared to dispersion. Thus the pollutant's scattering by spreading around the mean flow (dispersion) will be far less contributing to the overall spread (mixing) than the pollutant's physical movement with the mean flow (convection).

Phenomena contributing to mitigation

Keeping in mind that a large area (several thousand square kilometers) of aquifer has been affected and that it is not possible

Table 1. Groundwater structures operating in the arsenic-affected alluvial belt of West Bengal

Specifications	Heavy/medium duty tubewells	Shallow (low duty) tubewells	Tubewell with hand pump
Depth range	50 to 200 m	30 to 100 m	10 to 200 m
Tapping zone(s) thickness (average)	30 m	10 m	3–5 m
Size and design	(35 cm × 20 cm) (14″ × 8″ or (30 cm × 15 cm) (12″ × 6″ or (20 cm × 10 cm) (8″ × 4″) diameter	(7 cm or 10 cm) (3″or 4″) diameter	(5 cm to 10 cm) (2″ to 4″) diameter
Drawdown	6 to 12 m	3 to 6 m	Insignificant
Discharge	100 m^3/h	20 m^3/h	Small, discontinuous
Borehole	Gravel packed	Gravel/coarse sand packed	No specification
Use	Irrigation/water supply	Irrigation/water supply	Domestic water supply
Numbers	About 3000	About 1 lakh	Over 5 lakh
Pump	Electric/diesel pump, > 10 HP	Electric/diesel pump, ≥ 5 HP	Hand pump

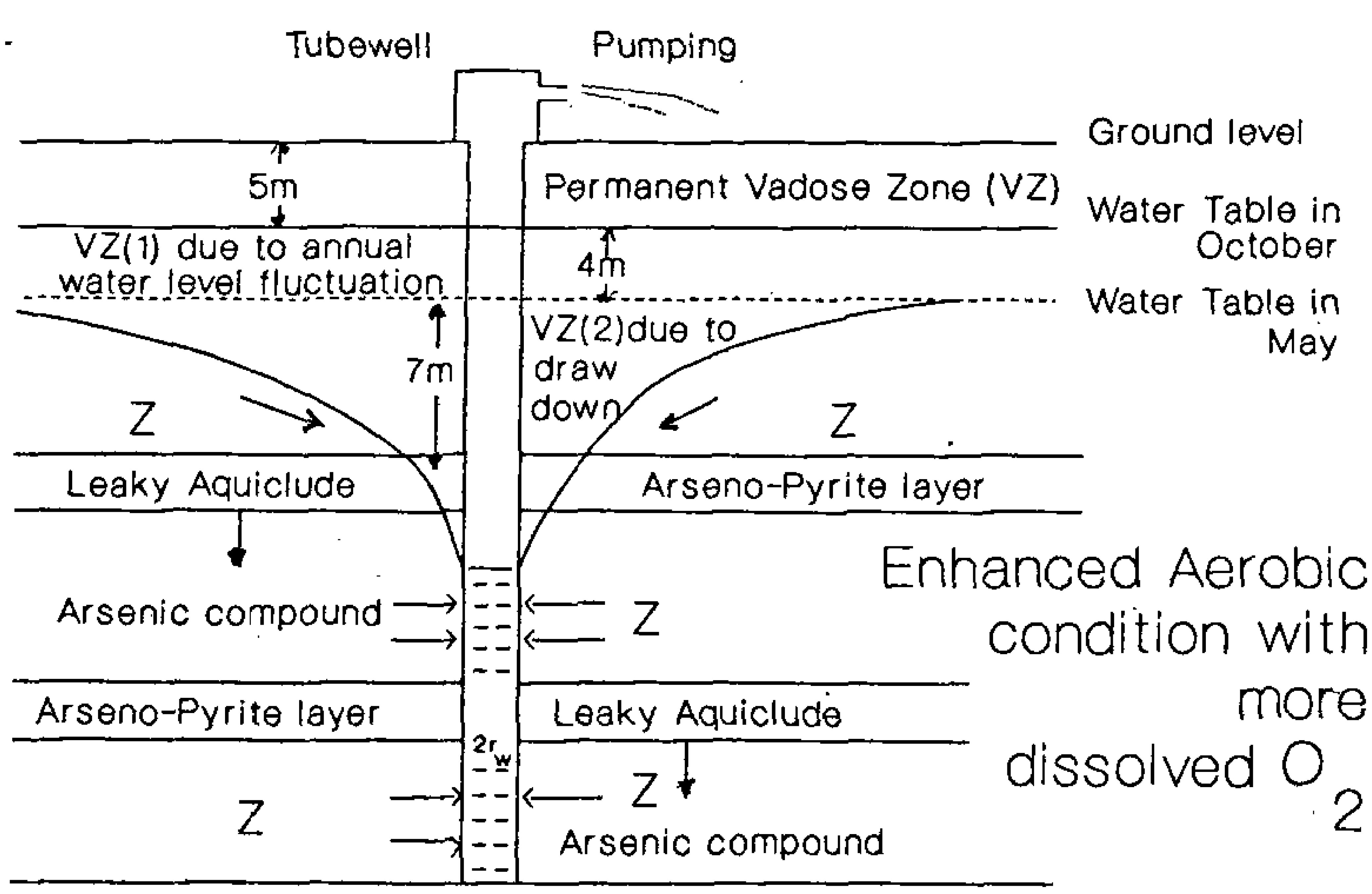

Figure 2. Aerobic condition in groundwater around a heavy duty tubewell in the eastern part of West Bengal. VZ(1) and VZ(2) are dynamic vadose zones; these and Zs are the mixing zones due to tubewell pumping.

to stop the spreading of underground arsenic once the process of leaching has been triggered, let us examine what are the factors which contribute to the alleviation of arsenic pollution.

(i) Recharge of arsenic-free rainwater. It is an established fact that every year about 4 m of aquifer water column, on the average, is getting recharged at the top of the summer (lowest) water table. This is equivalent to about 50 cm of rainwater amounting to half a million m^3 of water per sq km area. This huge amount of water is arsenic-free. If we can get this recharged water mixed with the shallow aquifer, say within 50 m of depth and also withdraw this water annually, then mitigation is started. For this purpose, future tubewells of all duty can be restricted to a depth of 50 m, so that these act as underground mixing tools as well as tubewells for the purposes that they are being used now.

(ii) The arsenic removal system patented by CSIR–Jadavpur University could be used more pervasively in the areas where arsenic contamination in groundwater is observed.

(iii) It is not advisable to exploit deeper aquifers extensively as they may ultimately get contaminated with arsenic. The safe limit of arsenic in drinking water is so low (0.02 ppm) and the mixing phenomenon by tubewells is so prominent that exploitation of underlying deeper aquifer may not be feasible without running the risk of it getting contaminated after some time. Also, mitigating deeper aquifer is more difficult and costlier than manipulating/managing the shallow aquifers.

In conclusion, it is reiterated that all the above discussions are based on the fact that the source of arsenic is geological and the mixing mechanism originates from arsenic-leaching. This has to be established by further scientific work. An idea about the occurrence of arsenic-bearing layers and the amount that can be leached out to the aquifer under present conditions are to be investigated. A mathematical modelling approach backed by borehole data may perhaps form the basis of such studies.

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