A process for organic water

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We present a local, self-sustaining, natural and economic way to secure a quality drinking water resource for a town or city. Most local rainfed aquifers in the environs of cities suffer from long-term contamination by chemical waste – either fertilizers and pesticides or urban effluents. We propose a process by which such aquifers can be restored to quality. This is accomplished by first changing the land use of the catchment area of local aquifers to forest, and then by a yearly evacuation of water in the aquifer till quality is restored. A model is used to estimate that, typically, by yearly evacuation of the aquifer, pollution in the aquifer water is reduced to 10% of its initial value in 5–7 years. This is an organic process to purify the water in the aquifer. We also find that the area required for this falls within 10% of the total area of the city, well within the green area norm for a city.

Keywords: Chemical waste, green area, organic water, rainfed aquifers, yearly evacuation.

IT is common knowledge that our planet is faced with a major problem in the available water resources[1,2]. This problem has two dimensions:

(1) The first is with respect to the quantity of water available. With increasing population, the demand for water, both for human consumption and agriculture, has been steadily increasing. Also, the melting of glaciers, deforestation and general environmental degradation, in particular, of rivers, have cut the retentivity, flow and availability of water on the planet.

(2) The not so obvious problem, which is perhaps more serious, has to do with the quality of water, which has deteriorated over the last 50 years, so as to render most of it unfit for drinking. How has this happened?

Excessive urban migration has inflated cities beyond manageable limits, to produce such quantities of effluents so as to render both the local groundwater and rivers flowing by cities to be criminally polluted. This has happened mostly due to leaching of contaminants from landfills, indiscriminately disposed anthropogenic toxic waste, unplanned application of agrichemicals and surface runoff from farm lands[3].

More surprising is the state of groundwater in the rural areas which do not have waste-disposal problems like the metropolitan areas. The pollution here has occurred due to the heavy doses of fertilizers and pesticides used for modern agriculture. The cumulative effect has been to contaminate the near-surface groundwater base with fertilizers and pesticides. This pollution is long term and has no simple solution.

The USGS has extensive data available for the quality of groundwater for various kinds of land use across the country. One such set of data is shown in Figure 1 for the Long Island–New Jersey coastal drainages[4]. It is evident that the quality of water in the undeveloped areas is far superior to the one where there is urban or agricultural land use. The quality can only improve further for the case of a protected forest, where the root system of trees provides additional filtering of pollutants.

Quality drinking water is thus hard to come by except in wilderness areas, which are generally far away from the populations that require water. Transport of water from such areas to cities is then a high-entropy, high-cost, major pipeline project. Furthermore, transport of a fundamental and local resource like water is ecologically unsound and wasteful.

The other possibility for producing potable water is the technological fix of chemical treatment (reverse osmosis and resin), but this has the disadvantage of high cost, leaching of important healthy minerals – which yields only processed and not mineral water, and producing a sludge which causes a disposal problem. This makes it impractical for poor, underdeveloped and remote areas.

We now describe a process for purification of natural aquifers that occur in the environs of a human settlement, but have been cumulatively polluted by human activity over the years (we use the term 'human settlement' to mean any village/town/city and hereafter, we abbreviate it further to a 'settlement' throughout the text). The water stored in these aquifers is purified in the process and a local, self-sustained source of high-quality drinking water is created.

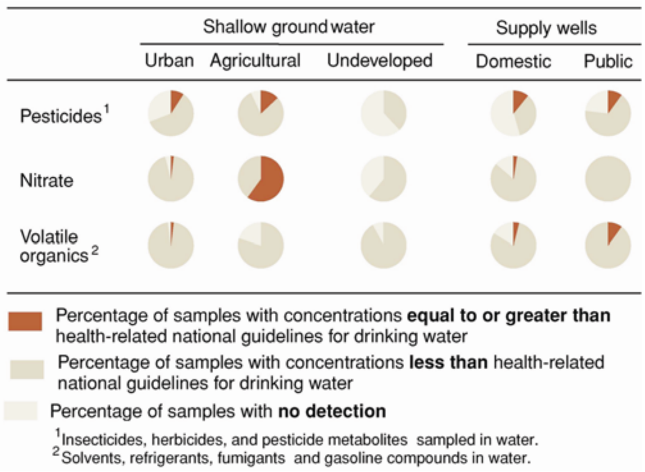

Figure 1. Selected indicators of groundwater quality for various kinds of land use in the Long Island–New Jersey coastal drainages.

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Using a conservative figure of 3 l per person per day, we get the annual requirement of drinking water for the settlement. Once aquifers with the appropriate recharge capacity have been located, we must create and protect forests on their entire catchment, so that the total recharge capacity is equal to or exceeds the requirement computed above. Further pollution can be eliminated by changing any urban or agricultural land use in the catchment to a protected forest area. This enables the water recharging the aquifer to be free from agricultural and other contaminants like fertilizers and pesticides (nitrates, phosphates, fluorides, etc.), and instead makes it rich in natural minerals.

A simple way to estimate the groundwater recharge for an area based on rainfall and pan evaporation data is presented elsewhere[5]. After estimating the total evaporation loss and subtracting it from the total rainfall, we find the balance available for recharge and run-off. For a large and heterogeneous area, the aquifer potential or recharge has to be determined from the hydrogeology of the area. This can be done using, for example, empirical data from the curve number technique, which gives the recharge from the porosity data of the local terrain.

Once the land use in the catchment area of the aquifer has been changed to forested land, our process of purification involves yearly evacuation of water in the aquifer by pumping out for agriculture (or other use) to a location outside the aquifer catchment. The efficacy of this method is illustrated using a simple but realistic model.

After annually pumping out the contaminated water in the aquifer for a period of 5–7 years, the fresh recharge flowing into the aquifer through the protected forest then gives us high-quality spring water ideal for drinking. We call this as ‘organic water’. As outlined above, the process involves an integration of natural processes.

One of the most pressing issues in this process is the timescale in which the water in aquifer can be decontaminated and purified. We now turn to this. Once the land use is changed and no fertilizer is applied to the ground, the unpolluted rainwater will pick up contamination from the top sublayer, leaving it less polluted in its passage. The rainwater will then move to the next sublayer carrying some pollutant picked from the previous sublayer. Assuming the same initial pollutant concentration (uniform) in the sublayers, the concentration in this sublayer, after mixing with the incoming rainwater, will be more than that for one sublayer above. Thus, the pollution concentration gradient in the soil will be positive with depth. Every succeeding rain will keep lowering the concentration of the pollutant in the soil, thus washing it into the aquifer.

We shall consider this problem using a simple model shown schematically in Figure 2. This model needs some relevant parameters to be specified. We discuss below, stepwise, these parameters, details of the model and the results.

(i) We assume an unsaturated zone of porous soil of depth, H. This is simply the layer of soil that starts at the ground level and extends down till the subsoil level at which the aquifer begins. A unit volume in this layer fractionizes thus: m is the volume fraction of polluted water which we term specific moisture, s is the volume fraction of soil matter, leaving a fraction $(1 - m - s)$ as empty volume.

(ii) Rain falls on the ground, which is the top of this layer. On subtracting the loss due to evaporation and run-off the balance, which is the recharge rainfall, percolates down through it to the aquifer. We shall consider only soluble contaminants (as insoluble ones will not percolate down in the recharge). The model does not distinguish between contaminants.

(iii) We have a dilution model of pollution, in which we assume ideal mixing between the specific moisture in the soil and the inflowing rainwater. Thus, when a certain volume of rainwater enters a sublayer of the soil, the pollution concentration in the sublayer becomes the weighted average of the two.

(iv) The initial pollution concentration in the soil and its depth profile are inputs to the model. For simplicity and convenience in discussing the model, we take the initial concentration of pollutant to be uniform through the depth, H, of the unsaturated zone. However, the model equations apply to any given concentration profile.

(v) A difference equation for the above model can be written in the following way. Each rainfall event results in a recharge pulse of at most a few centimetres of water

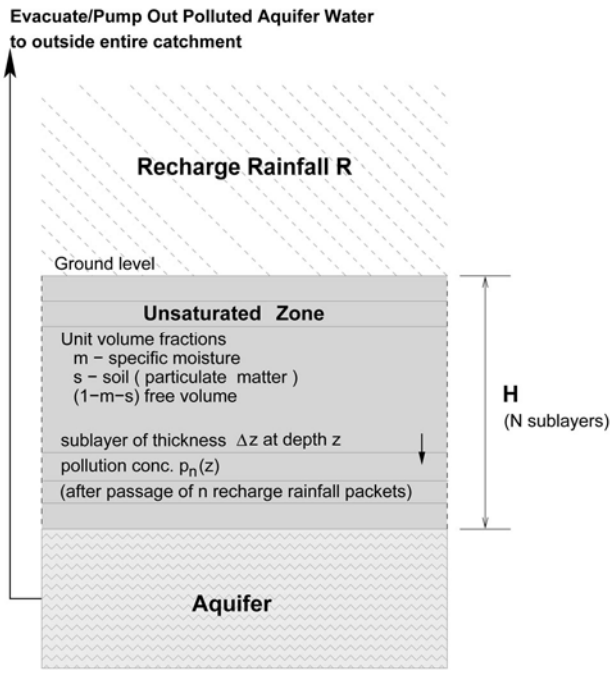

Figure 2. A schematic of the model for purification of unconfined aquifers.

percolating down into the ground. The total depth H is divided into N sublayers, each of depth $\Delta z = H/N$. Rainfall recharge is then divided into small packets of height $\alpha\Delta z$, such that the recharge water at most completely fills the empty volume in the thin sublayer. Thus, $\alpha_{\max} = 1 - m - s$. Choice of the size of recharge rainfall packet, and consequently the value of α is not important, as the results are independent of this.

Consider a thin horizontal sublayer of unit area and thickness Δz at depth z below ground. Let $p_n(z)$ be the pollution concentration in this thin sublayer at position z after n packets of recharge rainfall have passed through the sublayer. Recharge rainwater with volume $\alpha\Delta z$, carrying a pollution concentration $p_n(z - \Delta z)$, enters this sublayer from the sublayer above at $(z - \Delta z)$. The incoming recharge water mixes completely with the specific moisture in the sublayer, having pollution concentration $p_{n-1}(z)$, lowering the pollution concentration in the sublayer. With no sources or sinks of water in the sublayers, this mixing can be expressed mathematically as:

$$p_n(z) = \frac{m p_{n-1}(z) + \alpha p_n(z - \Delta z)}{m + \alpha}. \tag{1}$$

Given an initial pollution concentration profile, eq. (1) can be solved iteratively, as each packet of recharge rainfall percolates down the sublayers, to obtain the new profile of pollution concentration after the passage of the rainfall packet. The profile depends additively on the number of such packets. Thus, the heterogeneity of rainfall over the year does not play a role. Only the total recharge rainfall is of consequence. The new profile can be plotted, after a number of packets equivalent to the average total yearly rainfall have passed through the sublayers, to monitor the yearly pollution concentration profile. We, therefore, present the results in terms of the total effective annual recharge.

We have ignored effects of diffusion in deriving the above equations. Diffusion terms do not affect the average velocity of downward displacement of pollution. It is also straightforward to have the specific moisture m depend upon depth. In this case, m gets replaced by $m(z)$ in the above equation.

Our results are summarized by the simplistic piston model[6] and are consistent with it[7]. It states that purification is achieved when the total recharge inflow, which is the annual recharge multiplied by the number of years, is equal to the specific moisture, m, multiplied by the depth, H.

To understand this better we need to breakdown the hydrology of precipitation, P, into its various and distinct parts. Once rain falls on any area, first, there is surface evaporation loss, S. This depends on the climate and the soil. Next, we have to account for run-off and transpiration from the vegetal cover. For example, on flat agricultural land or flat pasture or woodland, the run-off is small, and for forests, transpiration is more than that for the pasture. On the other hand, on land that is contoured by slopes, a large portion of the balance goes in the run-off. Also, if the soil is impervious, like clay, run-off is dominant. Depending on their geographical location, aquifers present varying situations.

There are four main parameters in this estimate.

(1) Rainfall: (i) A rainfall, $P \sim 50$–60 cm, presents arid condition. This would apply, for example, to Delhi, where after surface evaporation, only 15 cm may be left for recharge, transpiration and run-off, of which we find 60% recharge for the forested catchment, or 9 cm of recharge. (ii) A rainfall, $P > 100$ cm (e.g. Bangalore, Pune, Dehradun) will have no more evaporation than in (i) above and could leave 75 cm for recharge, transpiration and run-off, of which as much as 30 cm or more may be available for recharge.

(2) The specific moisture or field capacity, m: (i) For sand, $m = 0.05$ (e.g. desert conditions in Rajasthan, Gujarat). (ii) For sandy loam as occurring around some areas in Delhi, $m = 0.15$. We shall use a typical average value of $m = 0.10$.

(3) The depth, H, of the unsaturated layer can vary from aquifer to aquifer. We have shallow aquifers in mind, which can vary from $H = 10$ to 30 m, and for our estimation we use an average value $H = 20$ m.

(4) The specific characteristics of an aquifer: The ratio of the catchment area to the aquifer area, r. Assuming R to be the normal recharge (in cm), we can define a catchment augmented effective recharge $E_r = R \times r$.

Based on the above model, we present below results for a typical situation with the following parameters: Specific moisture $m = 0.1$, soil fraction, $s = 0.2$, effective recharge (annual), $E_r = R \times r = 35$ cm, depth of aquifer $H = 20$ m.

The initial groundwater pollution is assumed to be uniform. A yearly plot of the groundwater pollution profile is shown in Figure 3. The curves correspond to profiles

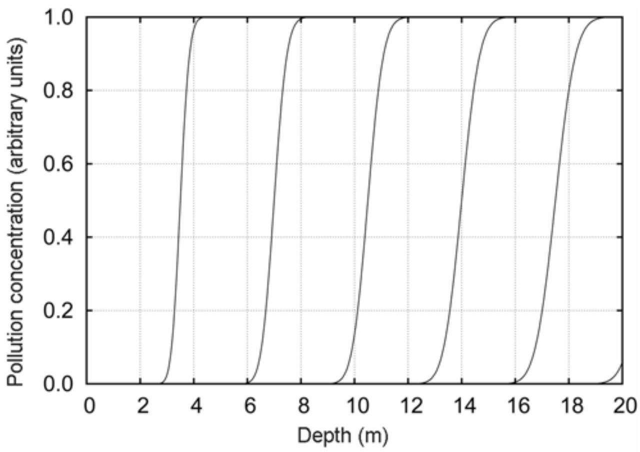

Figure 3. Groundwater pollution profile as a function of depth below ground into the unsaturated zone at yearly intervals after flushing with recharge rainwater. The aquifer is 20 m deep, specific moisture $m = 0.1$, soil fraction $s = 0.2$ and effective recharge $E_r = 35$ cm. The curves from left to right correspond to profiles after one to six years respectively.

after each consecutive year respectively. For the given aquifer characteristics, in 6 years the aquifer water pollution drops to about 10% of the original. In the absence of diffusion terms, the change in the slope of the profiles is an artifact due to a finite chosen value of the number of sublayers N and dz.

Implementation of such a scheme requires the following:

(1) An intervention in public policy that for towns and cities, all nearby aquifer catchments be declared vital state assets and be protected. To maintain water quality, the entire catchment area of the aquifer has to be protected – this area must fall outside the urbanized zone.

(2) Cooperatives or water companies to step in and manage drinking water services derived from these aquifers. This is highly profitable economically. The land we are talking about is strictly agricultural with its land use fixed and thus cannot be valued as regular real estate. The main cost is the renumeration to farmers who own the land. A renumeration of even four times the maximum agricultural income from the land, makes hardly a dent in the earnings from the service.

(3) A period of 5–7 years for such quality drinking water sources to be operational.

The main advantages of the process are that there is no use of chemical technology and no toxic waste is produced. It uses a natural percolation process for rainwater to come into the aquifer. Foresting the catchment provides good foliage and humus to supplement water retentivity. The roots of the trees consolidate the soil and provide additional natural filtration to enhance the quality of the water. Run-off and erosion are reduced, thereby increasing the groundwater recharge. Hence recharge estimates in the examples are lower bounds. Natural, green wooded area, which is less than 10% of the city area, is required for this purpose. This falls neatly into the urban planning norm of having about 20% green area in a city. Due to it being a natural process, the main costs involve the remuneration given to farmers whose land has been converted to wooded area. Even if the estimated remuneration is about five times the annual income of the farmer from the said land, the cost of generating pure drinking water of high quality is extremely cost effective compared to the ecological and financial costs involved in bottling and transporting water from remote, unpolluted wilderness sources, such as mountain streams, or purification of water by chemical or osmotic process.

At present, it is estimated that almost half the world's population has no access to good drinking water. This is considered an essential cause of several debilitating water borne diseases. This is the primary component in preventable human mortality. At a cost of US$ 0.02/l, the annual cost of providing 2 litres of good drinking water per day per person works out to approximately US$ 15 billion for every billion people. The UNEP experts have estimated[8] the cost of providing safe drinking water and proper sanitation to everyone in the world by 2025 at US$ 180 billion. Needless to say, the present cost in terms of health is much more. Providing a simple, natural, low cost, local and self-sustaining solution to the drinking water problem is vital. Organic water will do just that.

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Role of sorption properties and water status in control of seed longevity patterns

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The longevity behaviour of two oil-rich seeds, soybean (*Glycine max* (L.) Merrill) and safflower (*Carthamus tinctorius*) were compared using their water absorption properties. The nuclear magnetic resonance characterization of water in different moisture equilibrated seeds was studied in relation to the viability of both the crops. The component analysis of the transverse relaxation showed the presence of different components in soybean and safflower at corresponding relative humidity. Even though a more deleterious third component (structurally bound water) was observed at higher relative humidity in both the crops, the dif-

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