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Irrigation in Hilly Areas by Capillary Lift

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***Abstract:** Water can rise through a capillary up to a height of 34 feet (10 m) due to barometric pressure. This phenomenon occurs due to intermolecular cohesion, adhesion and surface tension. This characteristic can be suitably employed by using a bunch of capillaries tied together to lift large quantity of water. The problem is how to tap this water at the upper end as the same will not discharge on its own. This can be achieved by using a overhang of porous materials like sponge, cotton, carbon fibre, pumice stone etc. The extracted water can be collected in a tank at the upper end. By repeating the system at multiple levels, water can be lifted to any height without using any motor or pump. After considering the evaporation losses, this water can be utilised for irrigation purposes in the hills. This can also be directly fed to the roots of the plants by sheer capillary action.*

***Key words:** Capillarity, Green Energy, Irrigation, Porous Material, Surface Tension*

I. INTRODUCTION:

It has been observed during site survey that the ground water table on dry beds of seasonal rivers is much higher than the surrounding areas. The water table is the upper surface of the zone of saturation. The zone of saturation is where the pores and fractures of the ground are saturated with water. The depth may vary from few feet to 25-30 feet. The water table may vary due to seasonal changes (Photo plate 2). In undeveloped regions with permeable soils that receive sufficient amounts of precipitation, the water table typically slopes toward rivers that act to drain the groundwater away and release the pressure in the aquifer. Springs, rivers, lakes and oases occur when the water table reaches the surface. Groundwater entering rivers and lakes accounts for the base-flow water levels in water bodies. The following sketch depicts the general profile of the ground water table during summer and winter months. In hilly terrain, this is the only place where water is available at minimum depth below surface.

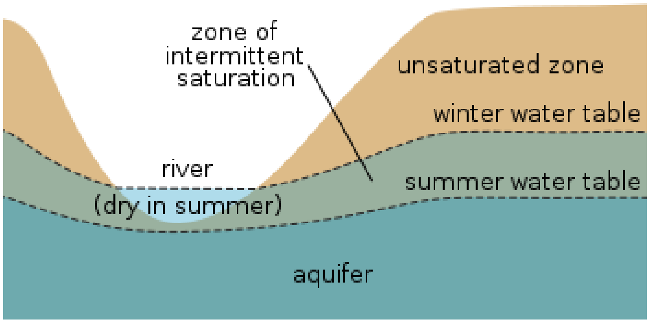

Photo plate 1: Seasonal Ground Water Levels

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This water can be lifted from below the ground level during summer when most of the seasonal rivers are dry. There is no water available from any source during this period except the storage tanks. This water can be lifted by employing submersible water pumps running on Solar-Wind micro grid. This can also be lifted by utilising capillary action in stages. The latter technique has been utilised for smaller application and has not been attempted for larger irrigation purpose. Both these techniques will entail digging of boreholes on the dry river beds.

II. BACKGROUND:

Many remote villages in hilly region are witnessing large scale human migration of inhabitants due to inadequate availability of water for farming (**Photo plate 1)**. Cultivation, if any, is totally rain dependant. Electric supply, even if existing, is neither stable nor economical for this purpose. However, Water is generally available in deep gorges, streams or below dried river beds during summer season. It needs to be lifted up to the appropriate height to be useful for terrace cultivation in higher reaches. This paper aims to develop a model of capillary lift of subsoil water **(J. Thomas et al, 2015)** for irrigation in hilly areas during summer season.

Photo plate 2: Overview of terrace cultivation in hilly areas.

III. DIRECT CAPILLARY FEED:

The water can be transferred directly to the plant root or drained to the surface using some porous material **(Z Feng et al., 2011)**. This technology is being conveniently used for irrigating potted plants to lift water from a lower level (**Photo plate 3)**. The same principle, suitably modified to a larger scale, can be easily used for fields just above the dried streams or around the houses through a porous medium **(Githinji et al., 2010)**. Multiple tubes, bunched together, on the lines of undersea fibre optic cable will be designed for this purpose.

The water provisioning system using the capillary action is a restoration propagation operation. It gives a constant and steady supply of moisture to the root zones of plants from the bottom up. Capillary irrigation needs even lesser water than drip irrigation. Drip is compulsive watering whereas capillary irrigation is impulsive i.e. the plant draws only the quantity of water that it needs for its botanical growth **(Sullivan et al., 2015)**. This is the natural process of absorbing the ground water by all plants and trees through capillary action **(Ityel et al., 2012)**. This project envisages providing water in dry zones.

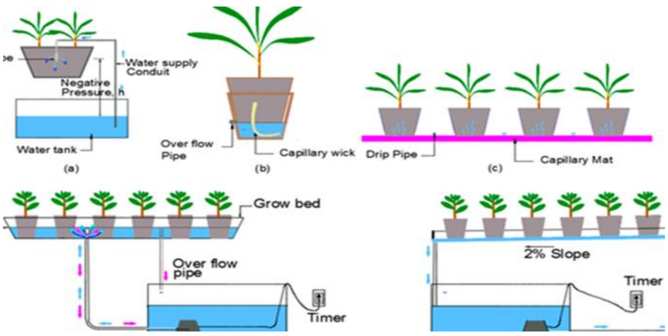

Photo plate 3: Capillary water lift

IV. CAPILLARY LIFT SYSTEM

4.1. SUBMERSIBLE PUMP:

Pits and boreholes are dug on the dry river bed of adequate diameter reaching up to the ground water table **(Photo plate 4)**. On clay soil and firm ground, there is no need of lining the borehole. However, in alluvial or sandy soil, lining will be required to prevent borehole wall collapse. The convenient lining will be some PVC or plastic pipe. The submersible pump is lowered into the borehole up to a depth where adequate ground water is available **(Photo plate 5)**. The pump will be operated with the power available from Solar-Wind micro grid. Number of such pumps can be deployed at several points depending upon the quantity of water required for irrigation. The water is pumped to higher storage tanks for further distribution.

Photo plate 4: BOREHOLE ON DRY BED

Photo plate 5: Submersible Water Pumps

4.2 CAPILLARY LIFT EXPERIMENT:

A simple experiment was carried out to demonstrate the basic principle of capillary water lift. A capillary tube was prepared by tightly stuffing cotton gauze into a thin plastic tube **(Beuther et al., 2010)**. The tube was submersed in a glass filled with coloured water **(Photo plate 6)**. Over a period of time the coloured water starts rising by capillary effect and is seen at the upper end. Slowly a droplet is formed on the bent portion of the cotton gauze **(Wesonga et al., 2014)**. The drop is released due to gravity. A new drop starts forming at the same point. The process continues slowly. To increase the discharge, multiple capillary tubes can be bound together.

Photo plate 6: Capillary Lift Experiment at Various Stages.

4.3 SUPERHYDROPHOBIC MATERIAL:

A team of researchers at Beihang University in China has created a very tiny pump that is able to lift a drop of water without the use of any power source and move it to a higher location **(Superhydrophobic "Pump")**. In their paper published in the journal *Advanced Functional Materials*, the team describes how they built their pump and the ways it might be used. As the researchers note, scientists have seen many examples of water being moved up from a lower location in nature, capillary action, etc., but not in the way they were looking for.

In this new effort the team looked to improve on such examples by taking advantage of both surface tension and a superhydrophobic material.

To build their pump, the researchers created a superhydrophobic material by exposing a copper mesh to an alkali solution—the microscopic sized pockets it created caused water to slide with almost no friction. They then affixed the mesh to the bottom of a plastic tube that sat vertically **(Photo plate 7)**. They next attached another tube to the first creating a right angle at the top and then attached a very short third tube to the second at its other end, this one pointing straight down. That was all it took. To use the pump, a bit of liquid was introduced into the pump, priming it, then a drop was introduced from beneath the pump, through the wire mesh. The liquid in the pump rose, because it was repelled from below, into the second tube and then into the third where it was expelled.

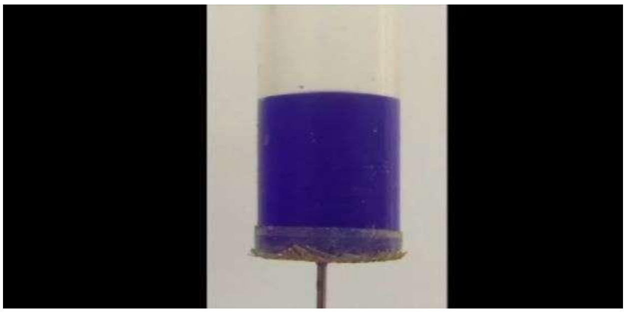

Photo plate 7: Capillary Pump Using Superhydrophobic Material.

The team notes that such a device can only pump to a few centimeters in height before gravity wins over, preventing the drop from entering, much less pushing other liquid up. They suggest it could be used as a design for advanced materials and in developing new kinds of technology applications in microfluidics, microdetectors or with intelligent systems.

Except for these details, there is no further test results or outcomes available. This is an issue which requires further exploration. The purpose of quoting this research work is to highlight the significance of the work on capillary lift being pursued all over the world to economically exploit this source of green energy.

4.4 CAPILLARY LIFT PROPOSAL:

Multiple capillary tubes with dia less than .1 mm, made of carbon fibre, can be bunched together in a casing for this purpose. The boring will be done on the dry river bed till adequate ground water is encountered for lifting by capillary action. The borehole can be lined or left as it is, depending on the nature of the soil. The multiple bunched capillary tubes, will be inserted till ground water table is encountered. A maximum depth of 34 feet can be reached for capillary lift of water.

The water rises in the capillary tubes due to molecular cohesion and surface tension. The water droplet formed at the top end needs to be absorbed or removed for further and continuous upward flow of water. In order to continuously drain out water from the top a plastic strip may continuously rub against the top surface of the bunch of capillaries. This removed water can be collected on a storage tank. From this second stage similar arrangement can be made to lift water to the next higher stages. Over ground level, the capillary need not go vertically but along the slope of the hill side, thus covering an even longer horizontal distance. This arrangement can be repeated along the length of the river for higher output.

In order to provide motion to the plastic strip, we can utilise a overbalanced wheel for free perpetual motion. The wheel rotates continuously due to gravity after initial push, as per the principle shown below **(Photo plate 8)**. Thereafter the motion is perpetual. Alternately, power generated by Solar-Wind micro grid can be utilised to rotate the wheel alternately. The water will keep rising continuously and will be stored in a higher tank. To increase the volume of water, a number of such arrangements can be made along the length of the river.

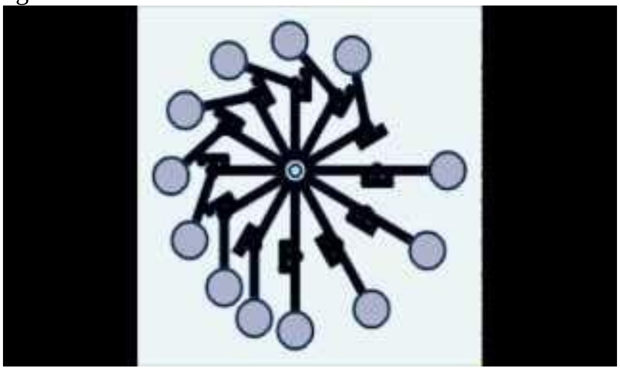

Photo plate 8: Perpetual motion due to shifting weight

The above arrangement will move in the clockwise direction. The perpetual rotary motion is due to automatic shifting of weight closer to or away from the axis. It may be understood that the arms on the right side will get extended and experience more gravitational pull, thus higher torque to rotate the wheel. Similarly the arms when coming to the left will get folded due to mechanical shifting of weight. This will shift the centre of gravity to the right and the wheel will rotate continuously.

The wheel needs to be perfectly balanced for constant rotation.

V. SUMMARY:

Due to barometric pressure water is lifted up to 10 m at MSL by capillary action. The capillary lift occurs due to inter molecular cohesion, adhesion and surface tension. To lift surface or subsoil water a bunch of capillaries are designed to be bound together for greater discharge. This has not been tried by anyone, anywhere but conceptually and practically feasible.

Subsoil water is available even in dry river beds at certain depth. The boring will be done on the dry river bed till adequate ground water is encountered for lifting by capillary action. The borehole can be lined or left as it is, depending on the nature of the soil. The multiple bunched capillary tubes, will be inserted till ground water table is encountered. A maximum depth of 34 feet can be utilised for capillary lift of water. In addition, the same system will be installed at number of places along the length of the river. Now the main problem is to extract this water at the higher end as it will not drain out on its own. For this purpose, sponge, cotton, carbon fibre or some super hydrophobic material prepared by exposing a copper mesh to an alkali solution—the microscopic sized pockets it creates causes water to slide with almost no friction, will be used at the delivery end.

The water once stored in a higher reservoir the process can be repeated any number of times for lifting it further to desired elevation.

VI. CONCLUSION:

Water obtained by capillary lift can be directly fed to the plant roots or stored in tanks at different elevations. From the tanks the water can be gravity fed to terraces for drip irrigation. The water required for the botanical growth of the plants by this process is less than 1% of what is normally used by conventional methods of irrigation. Using this system water can be provided to a certain height without the aid of mechanical devices like motor and pump. This method can be used to provide water to small plants and also to large plants in their initial growing stages. This largely helps in reducing wastage of water and helps in efficient use of water especially in water scarce regions. This system can be modified for more applications in the future. While direct capillary feed to the plants root is being utilised extensively but no work has been found for lifting water by bunched multiple capillaries. This social project needs to be promoted at governmental level in remote hilly areas to supplement irrigation and check migration. It is a vision for the future work with increasing scarcity of water all over the world.

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