

## Science Last Fortnight

### Water Stress in the Tapi Basin

Water from the river Tapi is a lifeline for more than 20 million people in west Madhya Pradesh, northern Maharashtra and in the southern parts of Gujarat. The population in the area has increased by nearly 50% over the last two decades. Regions that once had sufficient water now face water scarcity. What led to this? What can be done to improve the situation?



Image: Anup Sadi via Wikimedia Commons

Last fortnight, researchers from the Sardar Vallabhbhai National Institute of Technology, Surat and the IIT Bombay reported the magnitude of the problem of streamflow variability and water stress conditions across the Tapi river basin. Normally, higher rainfall leads to greater streamflow. But data on streamflow and rainfall from 1973 to 2013 broke this expectation.

The researchers took data on population and changes in land use as well as crop production statistics to examine the problem in detail. They divided the area into the upper, middle and lower parts of the Tapi river basin. In the upper reaches of the basin, they found greater streamflow than what could be expected from the rainfall data. The increase in streamflow could be due to deforestation, say the researchers. The forest area has reduced by nearly 10% in the area, reducing the capacity of the land to retain rain water.

Increasing areas of the basin's middle are under cultivation. Water diverted for irrigation reduces the flow. Irrigation has also led to high water loss through evapo-respiration. Excessive use of groundwater for irrigation, especially for *kharif* crops, is rapidly decreasing the groundwater table in the region.

Across the Tapi river basin, groundwater accounts for more than 60% of

water for irrigation. The groundwater table in the lower basin also shows a lowering trend. Since this is a coastal area, this increases the threat of salinity intrusion into groundwater, point out the researchers.

The streamflow in the lower parts has reduced considerably due to the presence of reservoirs and hydraulic structures upstream. The situation is worsened by increased urbanisation and industrialisation. The population in Surat, for example, increased from nearly 1.5 million to 4.5 million in the last two decades, and industrial units grew by more than 500%.

In spite of the increase in agricultural areas and irrigation, the food production capacity of the basin does not match the increase in population. The area under chronic water shortage increased from 34% in 1981 to 63% in 2011. Unless drastic measures are adopted, this can increase further.

The researchers recommend several strategic measures to reduce the water scarcity. These include rain water harvesting, prevention of leakage from existing water distribution systems, and efficient recycling of water at municipal and industrial establishments. Changes in irrigation practices – drip irrigation, lining of channels and levying of water charges on a volumetric basis – can also help reduce the problem of water shortage.

The team also suggests conserving water in storage reservoirs from the beginning of the monsoon. This can be done by adopting a robust early warning system for predicting inflow and subsequent releases from the reservoir.

DOI: 10.1016/j.scitotenv.2019.06.097

### Offshore Wind Energy Potential regions for projects

India is one of the top five countries in terms of land-based wind energy capacity. Given its extensive coastlines, there is a lot of untapped potential for developing offshore wind energy farms. But what are the best locations for establishing offshore wind farms?

Last fortnight, scientists from the Space Applications Centre, ISRO, and the Pandit Deendayal Petroleum University, Gandhinagar came out with an answer. The movement of air can be monitored from satellites using a scatterometer – a scientific instrument that analyses the return of a returning beam of light or radar waves scattered by wind movement, thus making estimates about wind strength.

The team took scatterometer wind data from the satellites of ISRO, NASA and the European Organization for the Exploitation of Meteorological Satellites. Using statistical methods, they assessed data from the different scatterometers separately. The data covered a period from 1999 to 2017, adequately long to make inferences on sustainable wind energy.

To validate the data, they also took meteorological data from offshore buoys deployed by INCOIS and the Research Moored Array for African–Asian–Australian Monsoon Analysis and Prediction.

The scientists say that scatterometers provide good estimates of wind speed. The combined scatterometer data proved a rich source that can be double-checked at various buoy locations. The combination provides accurate estimates of wind speed.

The scientists say that the Western Arabian sea has better potential than the Bay of Bengal with a higher mean wind speed of about 6.5 to 8 metres per second, above the 4 metres per second required to keep the wind mills running.

Kerala and Karnataka coasts have much less potential than some stretches along the coasts of Maharashtra and Gujarat. Offshore areas of the southern parts of Tamil Nadu seem most promising. The area between Dhanushkodi and Kanyakumari, in particular, has good potential for offshore wind farm development, say the researchers.

The study shows how such inexpensive data sources can be used to identify potential offshore regions for offshore wind farm projects.



Image: Ionna via Wikimedia Commons

Now to identify the exact locations, there is a need to use more filters. To reduce noise pollution, the wind farms must be far enough from the shore, yet the depth must be small enough to facilitate offshore structures. The locations should also not impact marine life or the livelihood of fishermen.

DOI: 10.1016/j.energy.2019.07.064

### Lotus Root Slices

#### *Aloe vera coating delays browning*

Lotus root is a delicacy in Asian cuisine. A rich source of dietary fibre, vitamin C and essential minerals, its storage poses problems. The root browns on exposure to air and deteriorates in quality.

Recently scientists from the Bahauddin Zakariya University, Multan and the University of Agriculture, Faisalabad, Pakistan reported a simple method for preserving freshly-cut slices of lotus roots using aloe vera.

The team cleaned and cut lotus roots into thin rounds. They also extracted gel from aloe vera and diluted it with water to different concentrations. After sterilising the solutions, they dipped the cut lotus roots into the pH adjusted solutions and hermetically sealed the slices. The slices were stored for eight days.

The team observed that weight loss and degree of browning were low in the treated slices. The solution having equal parts of gel and water, they found, was the best coating to improve lotus root shelf life.

The gel formed a protective layer and reduced electrolyte leakage and bacterial infection, says Sajjad Hussain, Bahauddin Zakariya University, Multan.

A 1 : 1 mixture of aloe vera and water is an effective way to prolong the storage life of lotus root slices. It delays browning, reduces microbial infestation and conserves quality char-

acteristics for 8 days, adds Sajid Ali, Bahauddin Zakariya University.

Aloe vera gel, being an edible plant product, is also safe for consumption. And the technique is easy to adopt at the household level, adds Ahmad Sattar, University of Agriculture, Faisalabad.

This simple, cost-effective technique for the long-term storage of perishable foods is a boon to the food processing industry.

DOI: 10.1016/j.scienta.2019.108612

### Effective Tillage Practices

#### *For reducing carbon footprint*

Greenhouse gas emissions from agricultural activities are a major concern. Studies show that plough tillage reduces soil organic carbon and increases carbon dioxide emissions by disrupting soil aggregates. Tillage also increases the erosion caused by wind and water. The Loess Plateau, covering over 600,000 square kilometres in central China, is such an area. The plateau's silt is washed to the plains in the north by frequent and destructive flooding. In fact, it is one of the most erodible areas on the earth.

To boost crop productivity in the region, farmers grow wheat in winter and maize in spring. And they practice conventional plough tillage which emits more carbon dioxide than do other agricultural practices. Can appropriate tillage practices reduce this footprint? Which practice is most appropriate for reducing the carbon footprint?

Scientists from the Northwest A&F University and the Ministry of Agriculture, China collaborated with a researcher at the Pir Mehr Ali Shah Arid Agriculture University, Pakistan to investigate. They opted for a split-plot design and initiated the experiments in 2007.

With winter wheat and spring maize in the main plot, the researchers created sub-plots with six tillage practices: plough tillage, no-tillage, subsoil tillage, plough tillage rotated with no-tillage, no-tillage rotated with sub soil tillage and subsoil tillage rotated with plough tillage. In all plots the crop residue was returned to the field after harvest and only half the recommended dose of fertilisers was used.

For nine years, the team monitored both crops from the plots with different tillage practices. Plough tillage had the least yield. No-tillage rotated with subsoil tillage gave the best results in terms of grain yield.

During crop harvesting, the team collected and measured not only the grain yield but also the biomass from crop residue, straw and root. No-tillage rotated with subsoil tillage turned out to be the best practice for increasing the yield, as well as the straw and root biomass for both winter wheat and spring maize.

The team collected soil samples from each tillage practice at different depths using a soil auger. Dried and sieved soil samples were used to determine stored carbon content. No-tillage rotated with subsoil tillage was again seen to be the best. While no-tillage led to accumulation of carbon at the surface, subsoil tillage increased the growth of roots, increasing the carbon in deeper soils. Rotation tillage resulted in a better and more even distribution of soil organic carbon storage than only tillage. The depth of soil containing carbon increased slowly in the nine years of the study.

Tillage practices had a significant impact on carbon footprint. Plough tillage showed highest loss of carbon from soil, while, for the rest of the practices, it was reduced. Conservation tillage exhibited higher soil organic carbon storage values than conventional tillage. The carbon footprint and functional unit-scaled soil organic carbon storage of winter wheat production were higher than those of spring maize production. And they decreased with increased planting year.

Crop residue return exhibited indirect effects on the carbon footprint, says X. Wang, Ministry of Agriculture, China.

Adopting agricultural practices with lowest carbon footprint is critical for developing sustainable agricultural practices for the Loess Plateau. So no-tillage rotated with subsoil tillage could turn out to be best for sustainable crop production, says Liyan He, Northwest A&F University, China.

These practices would also be helpful to control wind and water erosion in the area, says Qaiser Hussain, Pir

Mehr Ali Shah Arid Agriculture University, Pakistan.

DOI: 10.1016/j.jclepro.2019.06.161

### Treating Textile Waste Bacteria on jackfruit seeds

Reactive dyes in the wastewater from textile industries impact the environment. Adsorbents can be used to remove the dyes. But disposing of the adsorbents poses problems. Electrochemical methods can degrade the dyes but are complex to operate and maintain. Bacterial treatments are effective in dye removal, but are slow and require the adding of substrates for bacterial growth. Yeast extract, the most common co-substrate used, produces high organic carbon in wastewater. Moreover, since salt used for fixing the dyes is also present in textile wastewater, we have to use salt-tolerant bacteria.

Scientists from the IIT-Roorkee now report a way around the problem: jackfruit seed powder as co-substrate for bacteria found on jackfruit seeds. Jackfruit seed powder has earlier been reported to be an effective adsorbent for dye removal. The team suggests that, besides adsorption by the seed powder, the action of the associated bacterium is also involved.

The scientists washed, dried and powdered ripe jackfruit seeds. The seed powder was dissolved in distilled water. Then they dissolved the dyes, reactive red-21, reactive orange-16 and reactive blue-19, in water to get a concentration similar to that found in textile wastewater. They incubated the dye solutions along with jackfruit seed solution in a petri plate.

Only one type of bacterial colony grew in the medium. Using nucleotide sequencing and phylogenetic analyses, the team identified the species as *Pseudomonas aeruginosa*.

The team grew the bacteria in jackfruit seed slurry and took a single bacterial colony for the decolourisation assays.

After four days, they observed that the bacteria showed high decolourisation potential at a pH range of 6 to 9. There was 98% decolourisation for the red and orange dyes. Using spectrophotometry, the team analysed the

concentration of the dyes in the samples. While the red and orange dyes were degraded, the bacteria accumulated blue dye molecules and this was seen as mineralized structures in the cells.

The scientists compared the treated water samples supplemented with yeast extract and jackfruit seed powder as co-substrates. The toxicity of jackfruit seed powder was one-tenth that of the yeast extract.

The researchers estimated the phytotoxicity of the treated water by germinating green gram seeds in it. All seeds germinated well in the treated wastewater sample.

The scientists say that jackfruit seed powder can be directly used for textile wastewater treatment as the *P. aeruginosa* strain is native to jackfruit seed. The powder can be used as cost-effective co-substrate in textile industry bio-decolourisation processes.

DOI: 10.1016/j.jclepro.2019.06.328

### Oil from Coffee A natural surfactant

The foam on top of coffee is quite stable and stays for long. The foam is obviously caused by some surfactant. Surfactants are widely used in pharmaceutical, cosmetics and food industries. So what is the surfactant in coffee? Can we use it in food and pharma industries?



Image: Gita Madhu

Shweta Deotale and team from the Indian Institute of Food Processing Technology, Thanjavur investigated coffee oil for its molecular characteristics and surfactant properties. They chose oil from *Arabica*, which contains significantly more oil than other commonly cultivated coffee varieties. As with commercial surfactants, adding

coffee oil decreased the surface tension of the coffee solution.

They compared the properties of coffee oil with commercially available synthetic surfactants in aqueous solutions at various concentrations and found that a 0.03% concentration of coffee oil was critical for micelle formation. Further increase in concentration did not alter surface tension, say the researchers.

The team analysed foam structure in espresso coffee using a dynamic foam analyser. Again, the 0.03% concentration exhibited the best foam stability and lower coalescence for 6 to 8 minutes.

To identify the components responsible for the well-sustained foam, the researchers used nuclear magnetic resonance and liquid chromatography-mass spectrometry. They identified hydrocarbon chains with 10 to 15 carbon atoms as lipophilic/hydrophobic tails and chlorogenic acid, an ester of quinic acid, as hydrophilic head. These are the components responsible for micelle formation, they say.

The researchers then checked the hydrophilic-lipophilic balance value of the emulsions. The aqueous and fatty phases in the coffee oil emulsion did not separate for about a month.

Mass spectrometry confirmed the presence of polar constituents – caffeine, quinic acid and its derivatives. These compounds aid the surfactant to self-assemble during foaming, says Anandharamakrishnan, Indian Institute of Food Processing Technology, Thanjavur.

Coffee oil thus seems to be a suitable surfactant for applications in food, cosmetic and pharmaceutical industries. As a compound of natural origin, it is also eco-friendly. *Arabica* is the most cultivated coffee in the world and waste and by-products from the coffee processing industry can be a good source of raw material for such surfactants.

DOI: 10.1016/j.foodchem.2019.05.090

### Calcium Aids Auto-flocculation?

Microalgae are used for biofuel production. Harvesting microalgae by conventional methods such as centrifugation, dissolved air flotation, and

filtration, is expensive. Auto-flocculation, a cheap and efficient alternative, avoids the use of chemical flocculants. It is the residual calcium-phosphate present in the growth medium that induces auto-flocculation. However, studies using calcium-phosphate show that the extracellular polysaccharides released by the algae tend to obstruct this process.

Last fortnight, researchers from the COMSATS University, Pakistan and the Korea Advanced Institute of Science and Technology tried auto-flocculating microalgal cells even in the presence of polysaccharides. They hypothesised that calcium at an optimised concentration would form crystals of calcium-polysaccharide with positive charge, to flocculate the negatively charged microalgae.

To test this, the researchers conducted experiments with *Ettlia* sp. They studied harvest efficiency in four sets of growth media: natural growth medium, medium without polysaccharides and phosphate, medium with high calcium concentration and medium containing phosphate but no polysaccharides. Using optical density measurements, the researchers calculated harvest efficiency.

High harvest efficiency was achieved in natural growth medium, but only at pH 11. The chelation of calcium with the polysaccharides did induce auto-flocculation. However, the cost of the chemicals involved to increase the pH to that level is a deterrent to applications in actual field conditions.

The harvest efficiency of cells which were devoid of polysaccharides was very low, indicating the importance of polysaccharides in the flocculation of algal cells.

Contrary to expectations, experiments with a high concentration of calcium also showed low harvest efficiency. The team found that the calcium also interacted with phosphates to form calcium phosphate. The interaction of calcium-phosphate with calcium-polysaccharides led to increased positive nuclei that repelled each other and that, in turn, reduced interactions with the algae. To confirm the role of calcium in flocculation and its effect on harvest efficiency, the re-

searchers conducted dose response studies. The results showed that, at pH 11, even a low calcium concentration was enough to increase harvest efficiency and, at higher concentrations of calcium, flocculation decreased.

In the medium devoid of polysaccharides, adding phosphate increased flocculation even at lower pH. But polysaccharides are normally secreted by algae. So again, this may not be applicable in normal conditions. However, phosphate-based harvesting would be applicable to dilute microalgal cultures with low concentrations of polysaccharides, say the researchers.

Flocculation is better with calcium-polysaccharide interactions and this is disrupted by calcium-phosphate interactions.

The researchers then tried the same trick on *Chlorella* species. But that did not yield similar results. Calcium-polysaccharide interactions did not help in auto-flocculation. Co-harvesting both species did not help in increasing harvest efficiency either.

Auto-flocculation is species dependent and protocols to harvest cells using interactions of extracellular polysaccharides must be chosen prudently, say the scientists.

DOI: 10.1016/j.jclepro.2019.06.154

### Cement Industries

#### *Environmentally proactive?*

Polluting industries come under the ambit of environmental regulation. The cement industry, with its huge carbon footprint, is one such. However, the industry often proactively takes eco-friendly steps. What factors determine the willingness of the cement sector to take such steps? Arun Kumar Vishwakarma and Arvind K. Nema from IIT-Delhi, along with Shirish Sangle from the National Institute of Industrial Engineering, Mumbai decided to find out.

From existing literature and discussions with experts, they identified four possible determinants: organisational capabilities, market benefits, environmental risk management and pressure from stakeholders.

They formulated a questionnaire covering all possible subsidiary factors and conducted a pilot study with 115 respondents. After validating the rele-

vant factors through the pilot study, they designed the final study and administered a 49-item questionnaire to 195 respondents from senior, junior and executive levels of the industry. The respondents were all aware of the Global Reporting Initiative norms and the reporting of sustainability issues.

The results of path analysis of the four determinants showed that organisational capacity is the most crucial factor leading cement firms to adopt environment-friendly strategies. Market benefits also had a role. The roles of environmental risk management and stakeholder pressure seemed to be insignificant. This, the researchers say, may be because environmental risk management and stakeholder pressure are influenced by existing regulations and are usually warded off by legal compliance.

Thus, if the organisation has capacity, proactive steps are taken which help build brand image. It also makes sense to take proactive steps because environment-friendly consumers can make a difference to profits from the market.

Decision makers can benefit from this evidence-based study to improve environment-friendly practices in cement industries. Focusing on capacity building leads to eco-friendly proactive steps, and impacts market perceptions.

The researchers also compared their results with those from power industries in the same area, with the same socio-economic and political conditions. And found that the same factors did not apply to power industries.

Similar research, therefore, needs to be extended to other industrial sectors, whose determining factors for proactive environmental strategies are unknown.

DOI: 10.1016/j.jclepro.2019.06.291

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ACKNOWLEDGEMENT: IISER Pune for access to scientific databases.

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