CSIR-CSMCRI: Major Achievements in terms of R&D

1. Commercial production of seedling and farming of economically important agar yielding seaweed Gracilaria dura

The agar requirement in India is about 400 tonnes year^{-1}, while about 46 small-scale industries barely produce about 150 tonnes year^{-1} of agar. Considering this the economic potential of the seaweed sector in India, particularly agarophyte farming, has gained significant attention in recent years. The absence of a continuous supply of planting material is the bottleneck. The scaled-up propagule production (25,000 batch^{-1}) and out-planting of tank cultivated seedling material in the open sea was successfully achieved in agarose yielding Gracilaria dura. The propagules showed higher survival, regeneration, and growth. In view of impending commercial operations, Council of Scienific and Industrial Research, New Delhi along with Technology Information Forecasting and Assessment Council, Department of Science and Technology (DST), Government of India has sponsored the pilot-scale propagule production project at Manar, Gujarat. Central Salt and Marine Chemicals Research Institute, Bhavnagar has provided the technical support, while the industry partner is the Indian Center for Climate Societal Impact Research (ICCSIR), Mandavi. This is the first facility in the country which was established under public-private partnership mode. The indigenous production of feedstock for high value agar / agarose shall help in circumventing natural feedstock exploitation, protecting biodiversity, creating jobs and stimulating the economic growth in rural coastal areas of the country.

https://youtu.be/d360Fmvg0NA ; https://youtu.be/GtksWmRAhEg ; https://youtu.be/BnK5hRbyaU4

2. Demonstration of decentralized solar thermal dryer supported by The North East Centre for Technology Application and Reach (NECTAR)

Under a Memorandum of Understanding (MoU) between The North East Centre for Technology Application and Reach (NECTAR) and CSIR-NIScPR, a solar thermal dryer with a capacity of 25 kg/batch was designed, and demonstrated to community stakeholders for drying local agro/aqua products at the NECTAR's Technology Demonstration Centre, Guwahati by CSIR-CSMCRI, Bhavnagar in May 2023. The mixed-mode solar thermal dryer of CSIR-CSMCRI is an upgraded form of open sun drying where drying is achieved in a closed structure under controlled settings employing the solar energy. A solar-photovoltaic powered dehumidifier integrated with the system took care of highly humid atmospheric conditions of the north-east region and acted as a backup for off-sunshine operation providing uninterrupted drying. The methodology not only enhances sustainability by mitigating operational challenges but also contributes to a healthier ecology. This kind of solar dryer is a significant development in decentralized solar thermal systems.

(656) CSMCRI's work on decentralized solar thermal gadgets for rural sector - YouTube

3. Improving quality of salt with simultaneous recovery of sodium sulphate through scientific interventions in Nawa - Didwana region of Rajasthan

More than 400 salt producers are involved in the production of solar salt in the Nawa – Didwana region of Rajasthan. Recovery of quality salt is the major concern in the region. CSIR-CSMCRI has given S&T intervention by setting up pilot scale washing plant and sodium sulphate recovery plant. CSIR-CSMCRI has trained several clusters of salt producers on the salt recovery process. This increases return to the salt producers and enhances livelihood of salt producers by ensuring better results by improvement in quality of salt and recovery of sodium sulphate. This technology has been adopted by a startup in the region. In addition, the technology has granted Indian patent.

(656) CSIR-CSMCRI's research on Production of Sulphate of Potash (SOP) - YouTube

4. Installation of RO Plant for BSF Jawans at Bhuj district of Gujarat

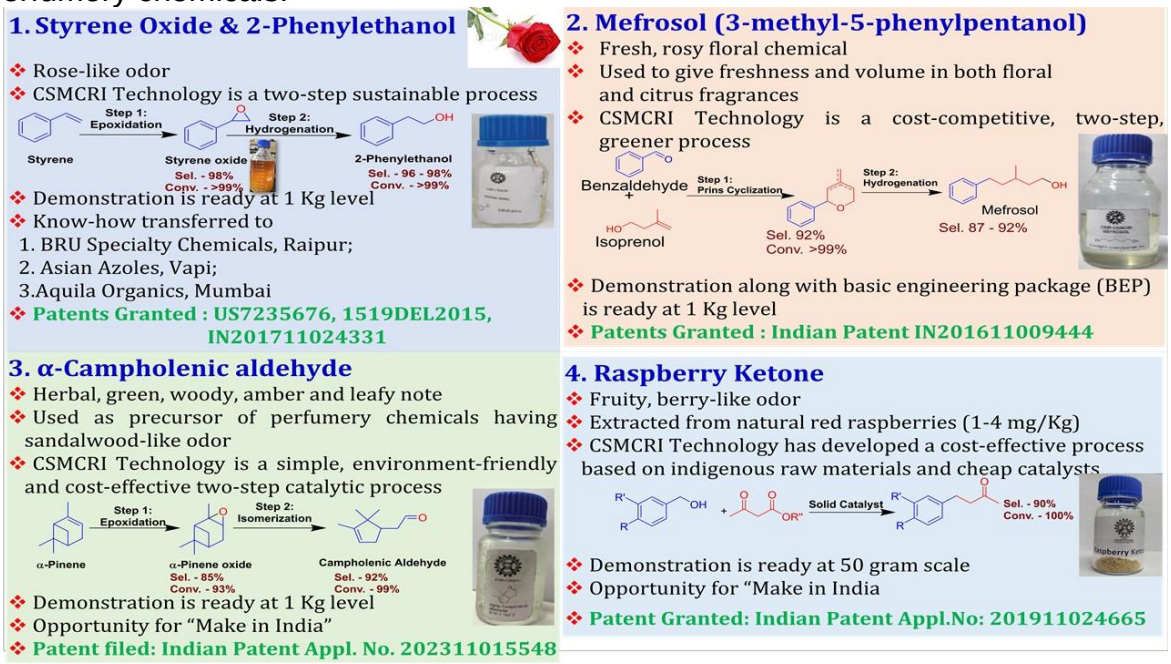
CSIR-CSMCRI designed, developed, installed, commissioned and maintained 0.1 MLD capacity RO plant at Khardoi post of BSF in Bhuj district of Gujarat. Indigenous brackish water RO technologies has been established in actual field conditions. The potable water as per WHO standards has been delivering to the BSF jawans on the Indo-Pak border. The process involves in passing of brackish water of TDS ranging from 10,000–12,000 ppm through the indigenous membrane technology incorporated RO desalination system, results in water of desired TDS (<500 ppm). This installation

results in provision of drinking water for more than 12,000 BSF jawans in the Bhuj district of Gujarat.

5. New catalytic process for perfumery chemicals

The increasing challenges in obtaining natural ingredients and the booming demand for perfumery chemicals in the commercial market creates the need for synthetic alternatives. Advances in catalysis and synthetic chemistry synergistically contribute to fragrance research. Challenge lies in developing the products with sustainable ingredients that are ecological sustainable. CSIR-CSMCRI has developed quite a few environmentally sustainable catalytic processes that enable the synthesis of array of perfumery chemicals/intermediates such as 2-phenylethanol, mefrosol, raspberry ketone, jasminaldehyde, campholenic aldehyde and carveol. These processes have the merits of employing environmentally benign reagents thereby a cleaner environment. These process/developments not only lead to significant cost reduction

but also increase the country's self-reliance through import substitution of the perfumery chemicals.



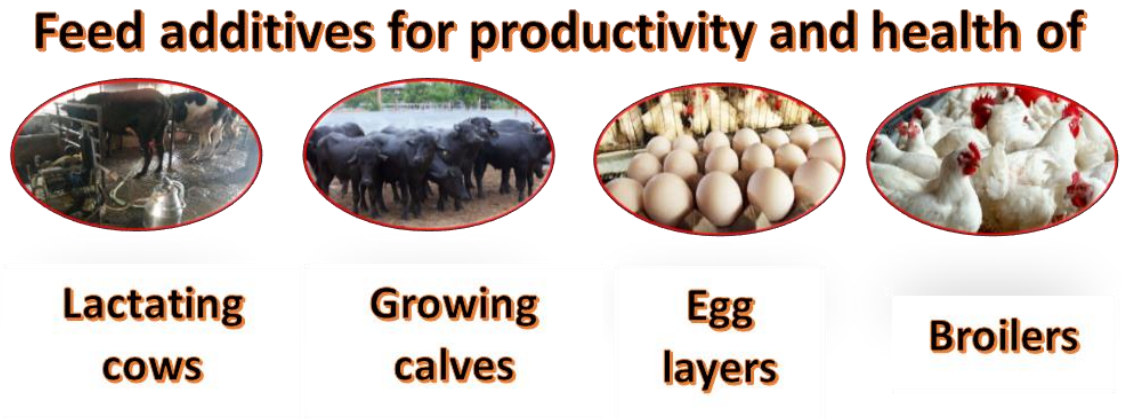
6. A ZLD management of molasses-based alcohol distilleries effluent (spent wash) with value-added products – potash & organics

Sugarcane is one of the most important resource to augment bioethanol availability. However, the effluent from ethanol distillery, commonly known as spent wash/vinasse, poses enormous environmental challenge, particularly in view of rising demand of fuel ethanol. Alcohol industries generate 8-15 L of spent wash for each L of ethanol produced. Spent wash is slightly viscous has high TDS, COD, BOD etc., and cause severe damage to the ecosystem. CSIR-CSMCI has developed technology that involves in systematic processing of spent wash to recover desalted organics which has been an excellent cattle feed ingredient, recovery of fertilizer grade potash which is of high demand because of its non-availability in the country and has been completely imported. This process enables complete recovery of water that is recycled back to plant/process/industrial use and ensures no ground water contamination from the distillery industry. This technology has granted with 3 Indian patents and two US patents. CSIR-CSMCRI also bagged "CSIR Technology Award – 2019" and "NRDC National Innovation Award – 2019".

(656) Pratyush Maiti Presentation | CSIR CSMCRI - YouTube

7. Seaweed formulations as animal feed additives

India depends heavily on agricultural and its allied activities for its occupation and economy. Poultry and cattle is always an integral part of the farming community. CSIR-CSMCRI has developed seaweed based new animal feed additive formulations for poultry (broiler and layers), milch cattle and growing calves for improving productivity and health. The product improves the overall performance of poultry and cattle by imparting better Immuno-responsiveness (Cellular mediated and HA titer). Consumption of the feed additive improves gut health (microbial & structural) especially in poultry that results in increased egg production and advancement in egg laying age. It enhances calcium and iron content in milk. Regular feeding of this feed result in notable reduction of GHG emission (Methane) by the cattle's. This technology has been transferred to Aquagri Pvt. Limited, Tamil Nadu.



8. **Process for preparation of liquid seaweed plant biostimulant (LSPB) from brown algae-Sargassum**

India being agriculture country, there is considerable demand for developing low cost bio fertilizer that can affordable even by marginal farmers for enhancement of crop yields & quality. The residue generated while producing liquid fertilizer can be used as a feedstock for making a commercially important products such as cellulose, carbon materials, for desired applications etc. It is tested for enhancing the crop yield & quality. LSPB and its solid formulations shows excellent enhancement in crop yields from 13 to 28%.

The fresh/dry seaweed biomass is liquefied to produce a seaweed liquid fertilizer which proven to be a promising low cost bio fertilizer (foliar spray as well as soil applications) and residue processed for recovery of cellulosic and carbon materials which may be used for suitable applications. Raw material (brown seaweeds) used are abundant in nature and easy to harvest.

India import large quantity of seaweed fertilizer that involves high foreign exchange exchequer (tentatively estimated at 800-1000 crore). Hence this technology has already been transferred to more than 15 industries for commercial production in India & revenue opportunity potential of licensee (in the near term) - ~50 crore. Several products are available in the market for commercial uses. In recent, KRIBHCO has launched seaweed biostimulant products for commercial applications.

KRIBHCO SIVARIKA: A Sustainable and Farmer Friendly Seaweed Bio-Stimulant

[(656) CSIR-CSMCRI's research on Seaweed - YouTube]

9. A zero liquid discharge process for the production of alginic acid and its derivatives from *alginophytes.*

During the downstream processing of seaweeds for the production of phycocolloids such as alginic acid, the major effluent produces is mixture of alkali and acids. The water usage is also very high and about 40% w/w of the starting material is produced as waste material during processing. These are the bottle-necks for the phycocolloid industry from processing point of view. In order to address these issues, a new process developed for the extraction of sodium (Na-Alg), ammonium (NH_4-Alg) and potassium alginate (K-Alg) without producing any solid and liquid effluents with yield of 25-30% w.r.t dry seaweed (IN 201711025753). *Sargassum Spp*. (*Swartzii*, *tenerrimum*, *wightii*), which is a brown seaweed collected from both west coast and south east coast of India was used to extract the above products. Na-Alg thus produced was converted to propylene glycol alginate (PGA Alginate). The viscosity of 2.0% aqueous solution of the phycocolloid at room temperature (30 ^oC) ranges between 300 to 800 cP.

The production of alginic acid and derivatives demands harvesting of huge volumes of seaweed biomass available naturally, which itself is labor intensive and create new employment opportunities in coastal regions. An industrial unit with capacity 100 kg/batch alginate production will roughly generate employment for about 50 people, which includes laborers for seaweed collection, pilot plant operation, product marketing etc. Since only 35% of the total domestic demand is fulfilled by the indigenous production of the phycocolloid and rest is imported, the products from the industries will able to reduce the import load of the country and will indirectly contribute to the GDP. Further, the process is zero liquid discharge and hence this technology is environmentally benign.

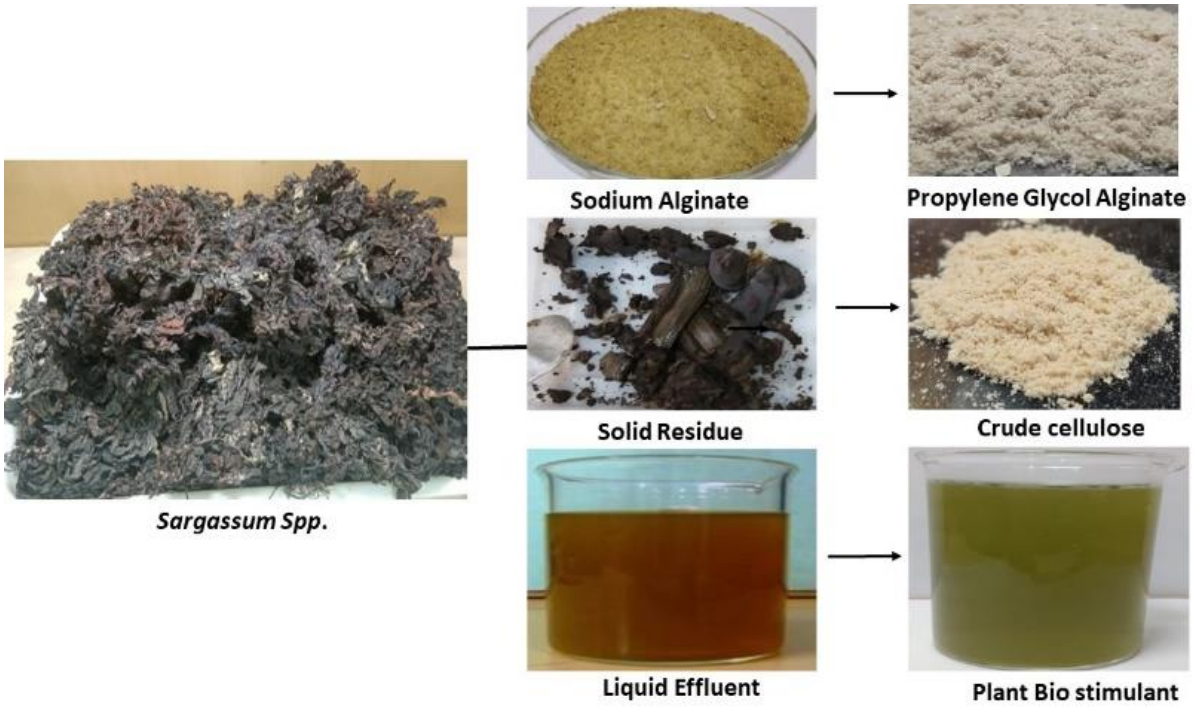
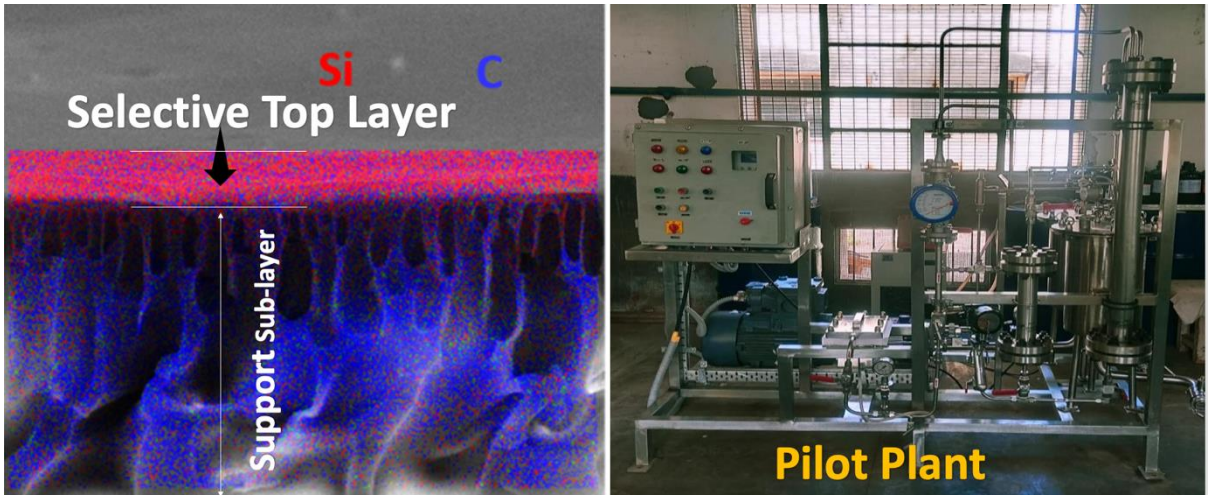


Figure : Zero discharge process for the production of alginates

10. Solvent-resistant membrane for separation in non-aqueous / industrial applications

A solvent resistant membrane consisting of three layers of which the top layer is a cross-linked polysiloxane, a middle layer of porous material and the bottom of polyester fabric was developed. The preparation consists of two main steps: the preparation of a porous support membrane followed by a coating of the support with a cross-linked polysiloxane (Singh *et al.,* 2020). The membrane can be used as a potential alternative to the energy-intensive thermal evaporation for solvent recovery for removing solvents from the extract of crude vegetable oil from oil-bearing materials. The membrane exhibits oil rejection efficiency >90% with an adequate process flux. Tech know how already transferred to M/S Permionics Membranes Private Limited. A pilot-scale membrane processing plant was jointly conducted with M/S Permionics Membranes Private Limited and CSIR-CFTRI, Mysore. It revealed the recovery of about 60% hexane through the membrane process for recycling in the vegetable oil extraction process. This corresponds to potential energy saving resulting to carbon footprint reduction in the environment.

This first attempt on pilot-scale evaluation of batch size 40 kg of crude miscella demonstrated the technical feasibility of the membrane process.



Singh, P. S., Ray, P., Subramanian, R., Chakkaravarthi, A., & Gopika, S. K. (2020). *Indian Patent Application No. 202011034405.* New Delhi: Indian Patent Office

11. **Kappaphycus seaweed cultivation and downstream processing technologies for making plant biostimulant and κ-carrageenan**

Earlier, fixed off-bottom mono-line and floating long lines were the two popularly followed methods globally for cultivation of *Kappaphycus*. There were several limitations and drawbacks with these methods where fish grazing was a serious problem. CSIR-CSMCRI went on to further refine cultivation technology by developing low cost 'raft cultivation with fish net bottoms' method modified to suit Indian conditions which circumvented the problems of grazing and drifting of material from seeding lines. Subsequently for high tidal amplitude sea coasts like Gujarat, tube net cultivation model was developed and implemented. Self-help groups were established in Tamil

Nadu, which through the support of industry (our licensee: M/s Aquagri Processing Pvt Ltd licensed in the year 2009) expanded the seaweed cultivation in the state of Tamil Nadu, wherein the seaweed cultivators started getting additional income to the tune of more than Rs. 15000 per month for 8 months in the year. Seaweed farming provides a new opportunity as well as a supplementary income generating activity for the existing fisher folk and people engaged in other ancillary activities. It is a new entrepreneurial opportunity, which does not lead to the displacement of the fishing communities from their local habitat.

Seaweed Processing Technology

Traditionally, it was customary to use dry seaweed for the production of gel-forming polysaccharide called κ-carrageenan. Most of the seaweed processing technologies used for food, feed, bio-stimulants or phycocolloids were designed for producing one single product. It is for the first time in the world where integrated process (US Patent No. 6,893,479) was developed for simultaneous recovery of two products (organic bio-stimulant and carrageenan) from harvested fresh seaweed, both products having great demand and commanding viable market prices. Our technology allows the entrepreneur to make the biostimulants at half the cost that is available through import. This makes the production process very competitive. It also allow our entrepreneurs to be less prone to the volatility which global carrageenan market faces. This enables to offer a fixed price to the cultivators in India while most cultivators in South Asia suffer during the periods when global market prices suddenly fall. The cultivation technology and/or processing technologies were since then additionally licensed to more than 10 entrepreneurs, many of whom have been able to commercialize the process and adapt it to specific market needs.

The sap derived from fresh *Kappaphycus alvarezii* proved an effective biostimulant which was validated on several agricultural crops through extensive optimization and multi-locational multi-crop demonstration trials undertaken in farm and farmer's field at more than 40 locations across 20 states of India in collaboration with State Agricultural Universities and ICAR Institutes. The yield improvement in about 10 different types of crops ranged from 11-37% over and above the recommended dose of fertilizers. This seaweed-based organic-bio stimulant contains over 50 naturally occurring bioactive metabolites as well as major and minor nutrients and is also a natural source of plant growth factors like polyphenols, enzymes, amino acids, organic acids, carbohydrates, vitamins, *auxins*, *cytokinins* and *gibberellins,* oligosaccharides that provide a major boost to crop yields by accelerating the plant's metabolic function. In addition, presence of thermo-stable glycine betaine and choline act as stress busters for crops. CSIR-CSMCRI contributed towards deciphering the science behind Kapppahycus seaweed based biostimulant with focus on understanding their action at plant physiological, biochemical & molecular level and decipher soil microbiome interaction, particularly under drought stress. It was established that application of seaweed biostimulants having low carbon foot print can significantly lower chemical fertilizer requirement and thus reduce chemical load and environmental cost, thus having significant impact on mitigation of climate change. Strategically, it also can help in decreasing carbon foot print per unit of crop production. The bio-stimulant derived from fresh living *Kappaphycus alvarezii* cultivated in Indian waters, is extremely effective and the first of its kind in the world. Globally the bio-stimulant industry largely uses brown algae harvested from naturally occurring seabeds, while our bio-stimulants

derived from red algae *Kappaphycus alvarezii*, which is cultivated in the coastal part of Tamil Nadu (India) by coastal community through SHGs. This makes the supply chain renewable and sustainable while providing viable livelihood opportunity to the coastal communities, largely comprising of women.

PHOTOGRAPHS

Fig 1 Kappaphycus alvarezii

Fig 2 Seaweed biostimulant being packed in Ms Aquagri's plant

(656) CSIR KAPPAPHYCUS CULTIVATION BY WOMEN - YouTube

(656) CSMCRI: Seaweed Farming & Processing in India - YouTube

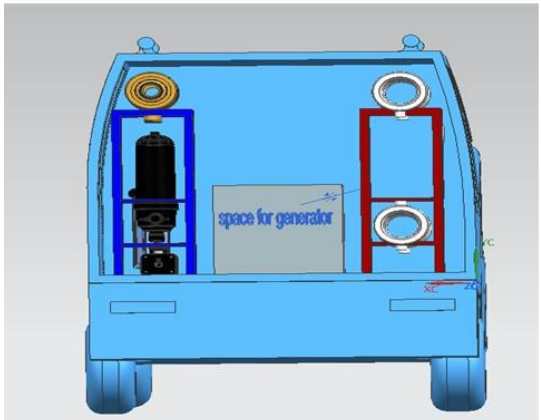
12. Design, Development, Installation, Testing, Commissioning & Deployment of Water Desalination & Purification Van.

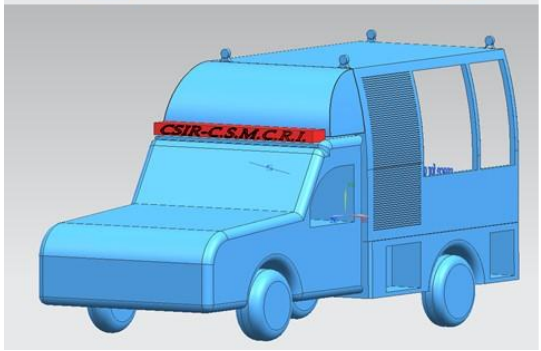
CSIR – CSMCRI, Bhavnagar has already designed and developed a mobile unit consisting RO & UF Plants for water desalination and purification. The key features of the mobile unit, which was inaugurated(Nov.2008) by eminent scientist, Professor C.

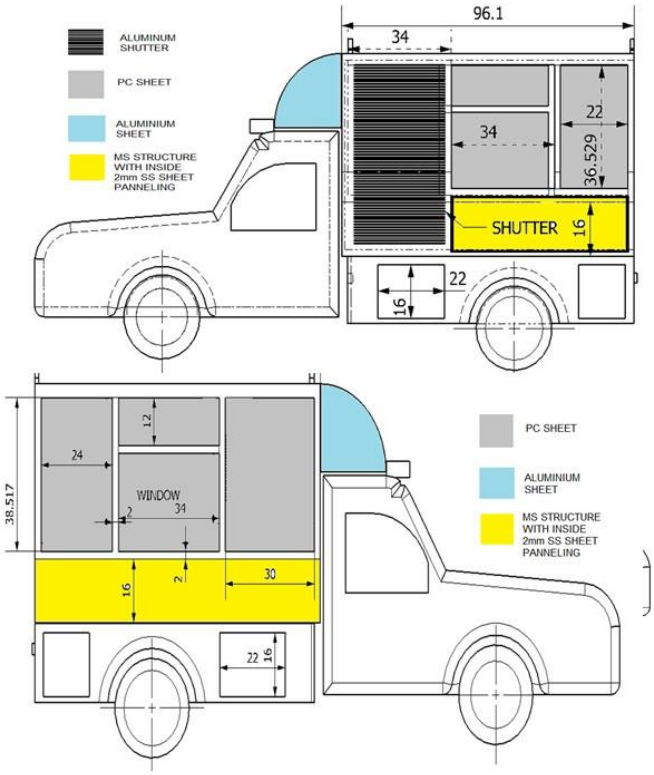
N. R. Rao, FRS is that the power(22 KW) required for the units is obtained from the van engine itself. The key motivations include: (i) Creating awareness among the public on indigenous water purification technologies, (ii) providing on the spot demonstration of the capabilities of the various water purification units – all the way from disinfection to fluoride/arsenic removal to seawater desalination(1000 LPH capacity) and 3000-4000 LPH Brackish water desalination capacity., (iii) being in a state of readiness to respond swiftly to emergency situations, and (iv) creating a model to serve a cluster of villages. One of the first missions the mobile unit was deployed for was mitigation of acute drinking water problems in North 24 Parganas, West Bengal in the aftermath of Cyclone Aila. The unit was stationed in the BSF camp and provided more than 30,000 LPD of potable water through desalination of saline(5000 ppm TDS) pond water. The RO permeate water pressure was adequate to the jerry cans placed in boats. These were then distributed to the distressed to the affected people in several locations. The Unit has recently served people during Uttarakhand floods and also during the drought in Latur (Maha.),Odisha (Phailin),Odisha (Fani-2019),Kerala Floods last Year. Thousand litres of potable water was distributed to the needier during the calamities and the Van has demonstrated the Indigenous membrane technology**.**

Existing RO bus

New RO van







[(656) CSIR-Central Salt & Marine Chemical Research Institute (CSMCRI) - Bhavnagar (Gujarat) - YouTube]