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Research Article

BRINE EVAPORATION RATE PARAMETERS MONITORING USING WIRELESS EMBEDDED SYSTEM

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ABSTRACT

In natural solar evaporation type salt production process, evaporation of water from the concentrated brine contributes major roll for crystallization of the salt. Surveying the recent trend, the evaporation of brine in the saltpan has been monitored manually and based on experience of the salt worker. For this he or she has to suffer from brine exposed on his/her body parts. The saltpan worker has to stay in harsh environment like temporary shed, scarcity of drinking water, environmental temperature variations from very low to a very high, and lake of basic amenities. The proposed embedded system introduced in this paper will monitor automatically the brine evaporation rate. The system is easy to install, highly portable and able to work in above mentioned harsh environmental conditions. It will eliminate the human intervenes in the monitoring process of environmental parameters for the given meteorological condition.

INTRODUCTION

Production of salt is increasing to meet world-wide demand and many of the new salt production projects due on stream by 2020 will produce salt via solar recovery methods. (https://roskill.com/news/roskills-salt-2017-conference-global-opportunities-new-era-salt-supply-chain/) The raw material for the salt is called Brine, mainly obtained from sea water. However in some region it has been obtained from lake or sub terrain. The type and quality of salt produced differs according to the source of brine, whether it is sea water or sub-terrain inland brine. India is the third largest salt producing country in the world after china and USA (http://saltcomindia.gov.in/industry_india.html?tp=Salt), among which the states of Gujarat, Tamil Nadu and Rajasthan produces approximately 96% of salt of the total salt production of the country Salt production in India is expected to increase over 35% to 40 million tonnes per year by 2020(Source: Business Standard.com). The conventional salt production a system in India is based on sea water solar evaporation method with huge human intervenes [2]. The solar radiation energy is significant contributor as the resource of evaporation of brine. Many more environmental factors are contributing in brine evaporation process[8][9][10]. Evaporation rate is affected by meteorological condition and salinity of water to be exposed for evaporation. A series of salt pan has been prepared in order to increase the concentration of NaCl as a result of evaporation. Now a day in major part of Indian salt production scenario, the evaporation parameters are measured and monitored manually. So human intervenes in harsh environment creates so many socio-economical problems for the involved salt workers in the production industries. The objective of this work is to minimize the frequency of manual inspections in the salt fields.

In Addition, evaporation from saline and hyper-saline lakes is important for evaluating vertical mixing (needed to establish nutrient distribution for aquatic life, energy production) mineral extraction and projection of future levels of saline water bodies when subjected to intensive human intervention[1].

Evaporation Rate

The influence of the two main climate parameters including irradiation intensity and wind speed on the law of natural evaporation rate has been studied through the indoor simulating system of environmental conditions[3]. Salt making from brine has a long history, which takes full advantage of solar and wind energy resources. Numerous studies have committed to convert

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brine to crystallized salt, but few, if any have attempted to research the evaporation processes [3]. Interestingly evaporation is often not defined in pure chemical and physics texts (for instance (Weast, Astle *et al*.1986)). This is because evaporation is a non-technical interpretation of more fundamental physical processes. Evaporation or condensation occurs when a liquid is not in equilibrium with its vapor or gas phase. Therefore, evaporation can be defined as the physical process in which a liquid is changed into a gas by molecular transfer. Condensation is the reverse process [5].

Increasing evaporation means doing one of the following,

- increasing the equilibrium vapor pressure of the liquid,
- decreasing the equilibrium partial pressure of the liquid in the ambient gas or air, or
- Increasing the rate of transfer from the liquid to the gas state [5].

Thus to change the water or any other liquid type from its liquid form to its vapor form is called evaporation. Significant energy is required in this phenomenon. In natural solar evaporation, the main source for this energy is the sun.

The air above evaporation pond becomes saturated with water vapor and this moist air must be removed in order to allow the process to continue. Several equations and field testing methods have been developed for determining evaporation rate. Considering the theoretical aspect, Penman equation determines evaporation rate of natural water surface exposed to solar radiation. The Penman equation was modified to reflect the reduced vapor pressure of a saline solution (Akridge, 2008). The modified Penman equation is presented as [6]:

$$\lambda E = \frac{\Delta}{\Delta+\gamma} R_n + \frac{\Delta}{\Delta+\gamma} f(u)(e_s - e) \quad \text{- - - - - - - - - - - - - - - (1)}$$

where: E= evaporation

λ=latent heat of vaporization

Δ=gradient of the vapor pressure-temperature curve.

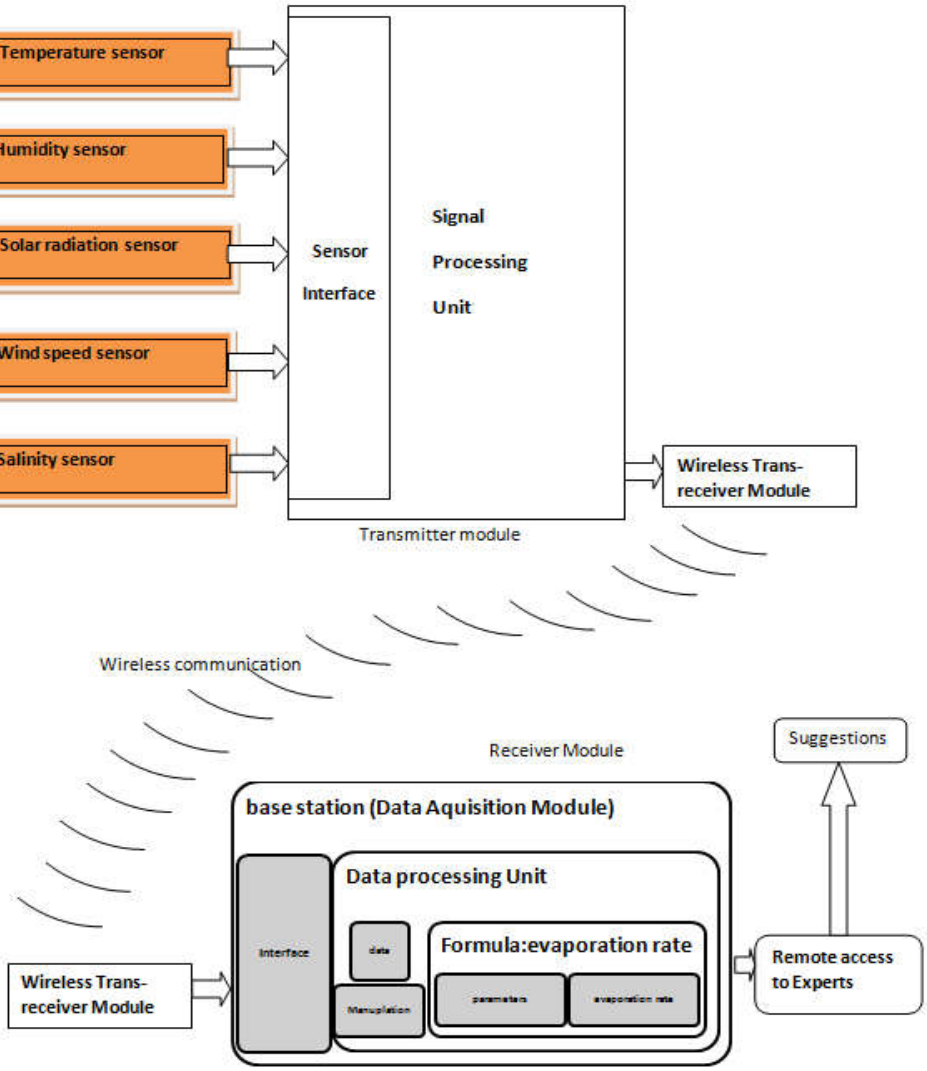
ϒ=psychometric constant (location specific)

R_n=net solar radiation

f(u)=function of wind speed

e_s=saturation vapour pressure (function of temperature and salinity $e_s=0.6108a_w\exp\frac{17.27T}{237.3+T}$ where $a_w=-0.0011m^2-0.0319m+1$, m is salinity of brine)

Schematic Diagram of Proposed System



e= ambient water vapour pressure (function of relative humidity $=H_r e_s/100$, where H_r=relative humidity) [4]

For given fixed area of salt pan, the evaporation rate is measured in mm /day

Factors contributing in Brine Evaporation

Considering above equation, the climatic factors and dissolved salt affecting the rate of evaporation include:

1. *Temperature*- heating the water molecules to the required temperature for vaporization.
2. *Humidity*- if the humidity level is high, less evaporation occurs as saturation level is quickly reached.
3. *Solar radiation*- providing required heat to enable evaporation
4. *Wind*- it will replace the saturated air with unsaturated air [6].
5. *Salinity*-concentration of salt and type of salt dissolved in water. As salinity increases, evaporation decreases. It shows that salinity has negative impact on evaporation rate. Leaney and Christen, (2000) indicated that the evaporation rate decreases exponentially with increase in salinity [7].

Proposed System and Methodology

The concept provides few significant technological challenges, however this paper describes the proposed system that is easy to operate and offers great flexibility in regular monitoring and controlling the various tasks of the natural solar evaporation type salt production For monitoring of above parameters like temperature, humidity, solar radiation, wind speed, salinity etc., each requires a sensor (or a common sensor for two parameters). In this proposed system all sensors are configured with a common signal processing module. If the output of the sensor is in digital form, the signal processing module does not require ADC (Analog to Digital Convertor) for that particular sensor. Provision of ADCs should make for the sensors having analog outputs. For this purpose ADC circuits or a microcontroller unit having enough number of ADCs can be used. Sensors must be properly interfaced with the signal processing module. In this interfacing process calibration of the sensor output must be cared. If in-situ data reading is required, one can configure a LCD display adjoining the micro-controller unit. This provision is optional and designer dependent. The ADC or Microcontroller unit of signal processing unit is then connected to wireless trans-receiver module in order to transfer the digital data of sensed parameters periodically. Now a day such wireless trans-receiver modules are available in the market which can accept directly digital output from the sensors and able to transmit it wirelessly[11].

At transmitter node sensor scheduling is an important task because wind speed and solar radiation changes considerably in short duration; these parameters should be monitored frequently. While the parameters like temperature, humidity and salinity of the brine do not change by considerable in amount over a very short period. As shown in the flowchart of figure-2, Wind-speed and solar radiation are sensed at every 3 minutes duration, in 15 minutes 5 readings are taken at node level and average is calculated after every 15 minutes. Duration for other parameters like temperature, humidity and brine salinity is kept 15 minutes. After every 15 minutes sensor data is sent to the base station via wireless trans-receiver module.

The transmitted data is received by a remote trans-receiver module same type as earlier used with sensor part, wireless trans-receiver module which is interfaced with the data acquisition module of the base station[12]. Received data is separated sensor wise and calculated respective parameter which is used in equation-1. Data is analyzed and manipulated at this stage. Data of the different parameters contributing in evaporation are stored at the data acquisition unit. Applying formula for evaporation rate, calculation can be done very easily. Third main part of the system is remote access to the experts. The expert relates evaporation rate with the brine level in the main salt pan, gives suggestion to the salt pan workers in order to improve quality and production of the salt. The main benefit of the system is that the expert has not to visit site frequently. Experts can give their feedbacks staying at their own place. Salt farm worker will execute the process as suggested by the experts. Also the salt farm worker has not to roam here and there in acres of salty land of salt pan to monitor the parameters. The system is useful for inland as well as marine salt production process of natural solar evaporation type. WSNs and data analytics allow the salt production industries to turn data into intelligence. They provide decision support through continuous real-time data capture and analysis to identify meteorological anomalies.

Transmitter Node Flowchart

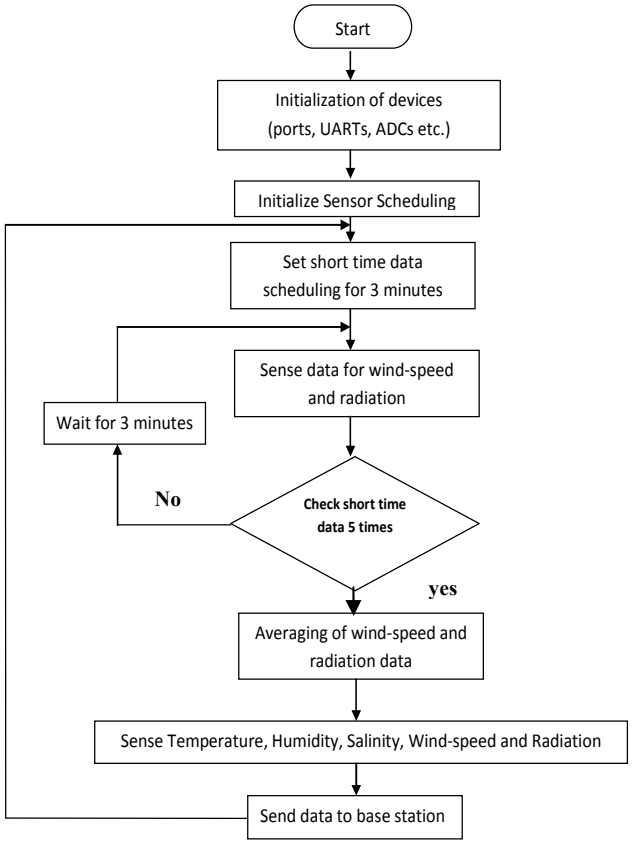


Figure 2 Flowchart for the transmitter node

Flowchart (Base Station)

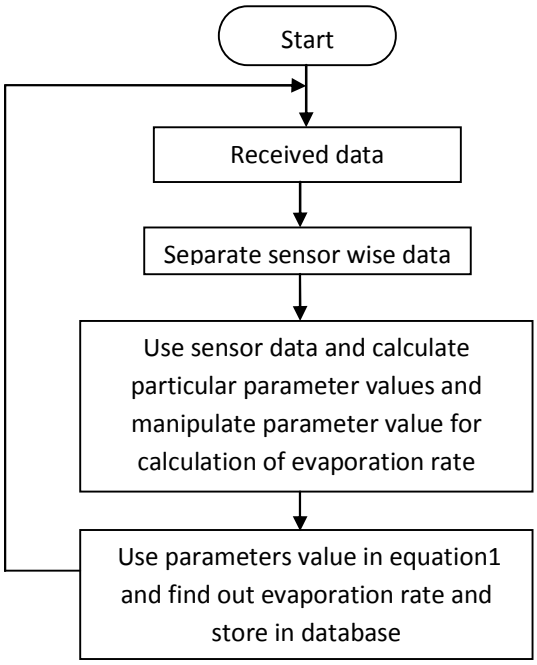


Figure 3 Flowchart of the base station

CONCLUSION

Data of the monitored parameters will be useful for experts to design control of the process**.** Once evaporation rate is monitored and calculated, the amount of the brine supply for the given time period will be decided. The brine evaporation rate decides the amount of real-time brine supply for the particular salt pan in natural evaporation type salt production process in which a series of salt pan is created for the evaporation. Supply of the brine in a saltpan can be synchronized with evaporation rate in order to maintain brine level in different pans of the series.

Proposed system will provide increased frequency of monitoring the parameters compared with manual data collection; improved data accessibility, data management and data use compared with traditional manual systems in which all data collected remains mainly unprocessed. This also permits combination of data from a wide variety of sensors and turning them in to information about the status of meteorological condition. The overall salt production is dependent on these meteorological conditions.

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