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Chapter

Energy Efficiency and Sustainability in Outdoor Lighting - A Bet for the Future

Kamrul Alam Khan, Salman Rahman Rasel, S.M. Zian Reza and Farhana Yesmin

Abstract

Electricity from PKL tree has been developed using PKL extract previously. In this work, electricity production has been developed using living PKL tree. It has been studied that an electrochemical cell has been developed using living PKL tree. The experimental data have been demonstrated in that way, hence this method is feasible and effective. Electricity has been conducted from PKL (Pathor Kuchi leaf) using PKL extract with positive and negative electrodes. Several research papers have been published on it in the recognized journal at home and abroad. This research work has expressed the electricity generation from living PKL tree. It can be found that due to the difference of the pH between the soil and the living PKL tree, electricity can be produced. The performance of this electricity has been studied. This work has been developed by authors, which produced electricity from living PKL tree without damaging the PKL plants. The unused suitable land areas such as hilly areas, forest areas, and coastal areas, those could supply clean power for remote communities all over the world.

Keywords: cultivation, living PKL electricity, performance, capacity, energy efficiency

1. Introduction

Pathor Kuchi leaf is known as a medicinal leaf from ancient time. It has a great medicinal value, it is used for different kinds of diseases like dysentery, cholera, typhoid, kidney disease, etc. In the West Bengal, India there is no alternative about Pathor Kuchi leaf for folk medicine. People are using the leaf as a folk medicine. But, nowadays, it is using to generate electricity for low and medium power production [1–18]. Generally Zn and Cu metal is used as an electrode and the PKL extract is used as a source of the electricity [19–38]. Clean energy sources, which are pollution free and environmentally friendly, are one of the key challenges of world's future society.

The traditional sources of energy oil, gas and coal are diminishing day by day rapidly. Bangladesh is mainly dependent on gas based electricity. Conventional sources of energy will be finished within 2100 across the world. We have to depend on renewable energy sources like solar energy, wind energy, biogas energy, biomass energy, geothermal energy, wave energy, tidal energy, OTEC and hydropower, etc. PKL power from living PKL tree is the source of biomass energy. It is an innovative work around the world [39–44]. The solar PV system is providing electricity in the

remote areas. But during night time it is needed battery which is expensive. So that living PKL tree power can play an important role to provide electricity along the remote areas across the world.

Pathor Kuchi leaf is known as a medicinal leaf from ancient time. Because it has a great medicinal value, it is used for different kinds of diseases like dysentery, cholera, typhoid, kidney disease, etc. In the West Bengal, India there is no alternative about Pathor Kuchi leaf for folk medicine. People are using the leaf as a folk medicine. But now a days, it is using to generate electricity for low and medium power production [1–18]. Generally Zn and Cu metal is used as an electrode and the PKL extract is used as a source of the electricity [19–29]. Sustainable energy sources, which are pollution free and environmentally friendly, are one of the key challenges of world's future society. Researchers discovered that living plants are literally "green" power source, which may become one of future's electricity supplies that perfectly integrates in natural environments and is accessible all over the world. The issues of the global warming are the responsible for the generation of electricity using conventional energy sources like oil, gas and coal. The climate change is distributed due to un-balanced eco-system around many part of the world. It is difficult to protect the world from global warming in an artificial way, although a numerous science and technologies are booming surrounding us. It was possible to produce 1.1 V using voltaic cell method. Some researchers were possible to get 1.221 V [45–60] using single Ag/Zn-Aloe Vera cell without using any kind of boost converter and conditioning circuit. If we can generate electricity from living plants or trees, everyone wants to be planting the trees in ones surroundings for getting electricity. Governments of many countries also suggested and motivated such a process of plantation of trees and plants to get electricity [61–75]. As a result, the number of plants and trees in the globe will also increase, which indirectly will save our planet from the serious issue of global warming by the process of plantation in near future. It may be said that living plant & tree power is improbable to replace the power sources for the most of applications after finishing the fossil fuels. Also this kind of living plants and trees electrical system could provide low cost, continuous, pollution free and sustainable power system around the globe.

2. Methods and materials

The research methodology of the project is described as follows:

The electrons are living around PKL plant roots those are a waste product of bacteria. PKL tree excretes organic matter into the soil, which is broken down by bacteria. The electrons are released in the breakdown process and then it is possible to harvest electricity by using electrodes without affecting the plant's and leaf's growth of the PKL in any way.

Figure 1(a) and **(b)** shows the PKL tree in a tub and **Figure 1(c)** shows the cultivation of PKL in the open field for electricity generation.

Figure 2(a) shows the cultivation of PKL electricity through PKL living tree's leaf and (b) and (c) shows the cultivation of tree's leaf electricity. **Figure 2(d-m)** also shows the cultivation of PKL electricity through PKL living tree's leaf.

Finally the methodology of the project can be divided by the following:

i. **Design and fabrication:** Easy assembly, low fabrication cost, long life and high production efficiency are the key factors of the design and the operation and maintenance would be simple, easy and low cost.

ii. **Field experiments:** The production efficiency of the project will be evaluated by field experiments. A set of experiments will be carried out.

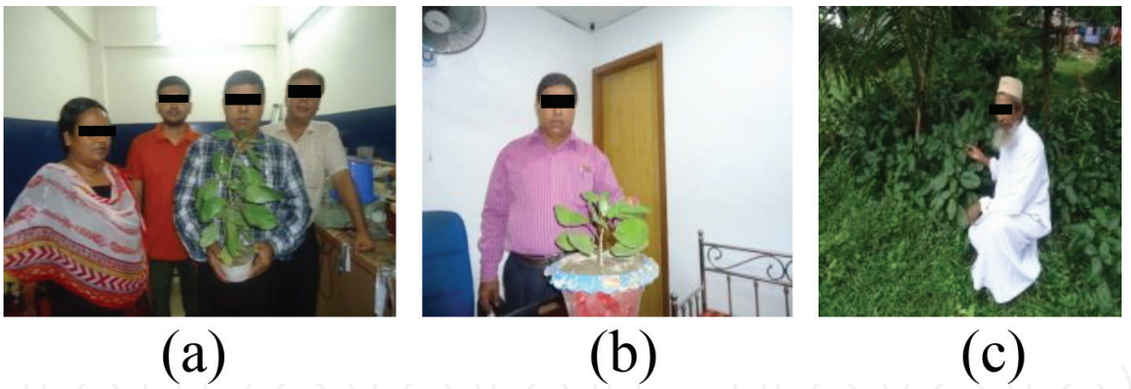


Figure 1.
Cultivation of PKL.

The effect of various factors such as open circuit voltage, short circuit current, voltage regulation, internal resistance, power & energy density, columbic efficiency, voltaic efficiency and energy efficiency will be observed.

iii. **Design parameter:** It may modify the design parameters of electricity production to fix any shortcomings regarding operational, maintenance, durability, quality and quantity. A further improved PKL electricity can be implemented in an arid, remote or a coastal area to remove the difficulties in acquiring green electricity and to save many human lives

iv. **Cost analysis:** The fabrication cost of PKL electricity will be calculated and be compared with other conventional techniques. The produced PKL electricity selling cost will be obtained and be compared with the commercial electricity price

v. **Electricity quality evaluation:** The quality of the produced electricity will be examined and monitored regularly to compare with PDB standards for electricity using.

vi. **A simulation model:** A theoretical production model of PKL electricity based on DC and AC theory may be developed

2.1 Definition of different parameters

i. Open circuit voltage V_{oc}:

The voltage without load is called open circuit voltage [51–53, 76–85]. Generally, it is denoted by $\mathbf{V_{oc}}$.

ii. Short circuit current I_{sc}:

The current without load is called short circuit current. Generally, it is denoted by I_{sc}.

iii. Voltage Regulation V_R:

It is defined by the following equation [54–60]:

$$V_R = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\% \quad (1)$$

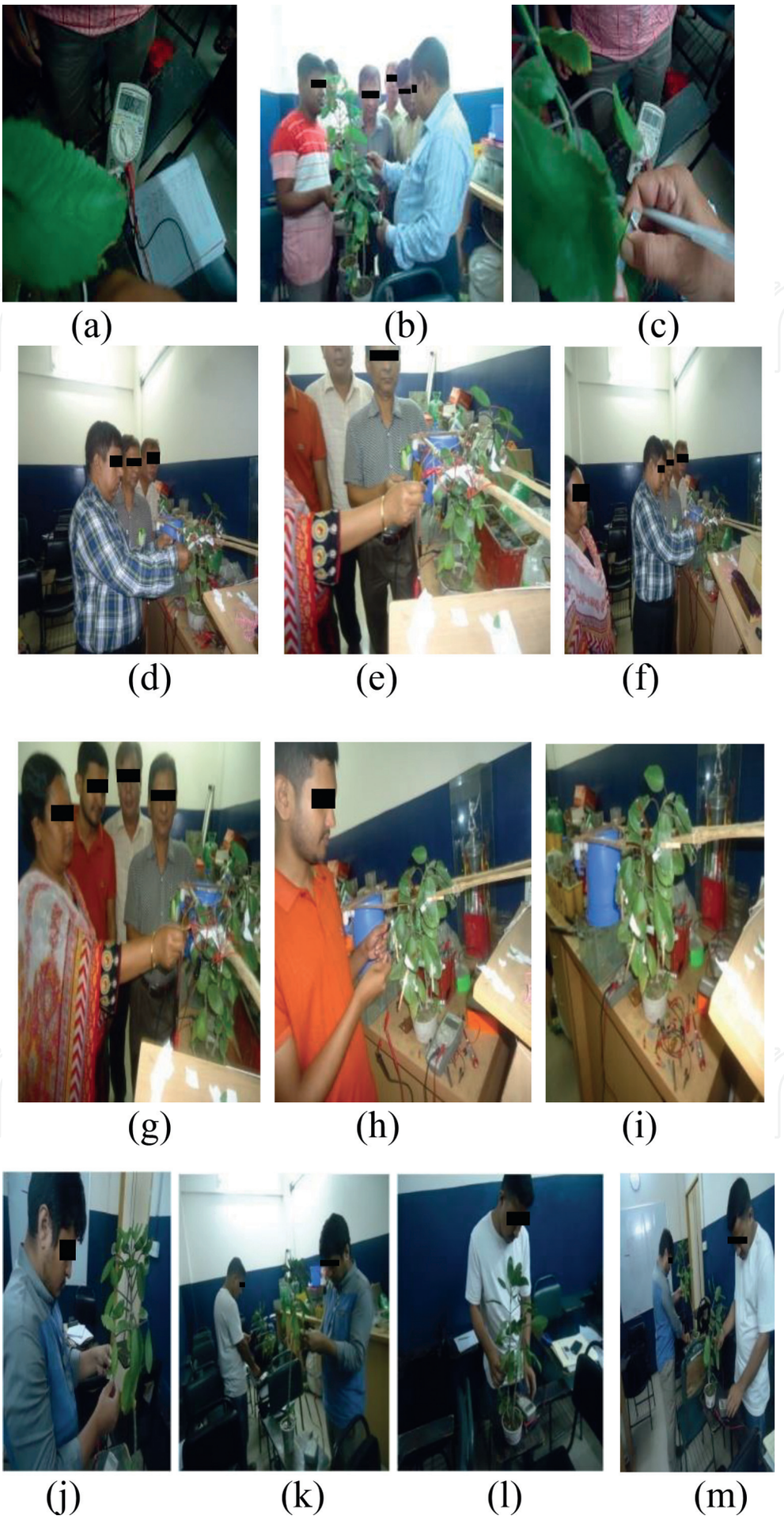


Figure 2.
Cultivation of electricity from living PKL.

where V_R = voltage regulation, V_{NL} = no load voltage, V_{FL} = full load voltage. Generally, $V_R \approx 0$ is desire, which is practically impossible [83–86].

i. PKL power density (PD) [83, 84]:

It is defined as the power extraction per kg PKL (Pathor Kuchi leaf).

$$\text{The Power Density (PD)} = \frac{\text{Power extraction (watt)}}{\text{kg}} \tag{2}$$

i. Energy density (ED) of PKL [85–94]:

It is defined as the energy (kWh) per liter:

$$\text{The energy density (ED)} = \frac{\text{power extraction (kWh)}}{\text{litre}} \tag{3}$$

Capacity of the PKL cell (AH) [95–104]:
How much current you will get for long time.
Generally, it is denoted by C.
$\therefore C = AH$
where A = current in ampere and H = Time in hour.

i. Energy efficiency of a PKL cell (η_c) [105–114]:

It is defined by the following equation:

$$\eta_C = \frac{P_{out}}{P_{in}} = \frac{V_{out}It}{V_{in}It} = \frac{V_D I_D t_D}{V_C I_C t_C} \tag{4}$$

where η_C = energy efficiency, V_D = discharging voltage; I_D = discharging current, t_D = discharging time, V_C = charging voltage, I_c = charging current, t_c = charging time.

i. Maximum power P_{max} [115–119]:

It is defined by the following equation:

$$P_{\max} = V_{OC} I_{SC} \tag{5}$$

where P_{max} = maximum power, V_{OC} = open circuit voltage, I_{SC} = short circuit current.

i. Load power P_L:

It is defined by the following equation [120–123]:

$$P_L = V_L I_L \tag{6}$$

where P_L = load power, V_L = load voltage, I_L = load current.

i. Fill factor:

It is defined as FF = $(V_m I_m)/(V_{oc} I_{sc})$, where V_m = useful voltage, I_m = useful current, V_{oc} = open circuit voltage, and I_{sc} = short circuit current [20, 34–38, 66–89, 124, 125].

ii. **Standard** PKL **cell condition:** The standard state condition of a solar cell is: The standard open circuit voltage of the solar cell is 0.5 V. The short circuit current of a solar cell = 0.5 A. The standard temperature of a extract of the

PKL cell = 25°C. The standard pressure = 1 atm pressure = 760 mm Hg pressure [90–114].

2.2 Vernacular name of the PKL

i. Stone chips

ii. Air plant

iii. Miracle leaf

iv. Mother of thousands

v. Mother of millions

vi. Leaf of life

vii. Devil's back bone

viii. Pregrant leaf

ix. Monekey's ear

x. Moneky ears

xi. Sotri

xii. Sotre, etc. [61–64]

2.3 Land situation in Bangladesh for cultivation of PKL

Total land = 55,000 sq. miles [24, 65–73]

$$1\,\text{square mile} = 640\,\text{acres}$$
$$= 3,500,000\,\text{acres}/2.5 = 14,080,000\,\text{hectors}$$

Total land (TL) in hector
Therefore, the nonagricultural land (NAL)
= 5,580,000 hectors.
The 2% of NAL

$$= 111600 \quad \textit{hectors} \times 7.5 = 837000\ \textit{Bigha}\ [1\,\textit{hector} = 7.5\,\textit{bigha}]$$

From 1 Bigha PKL, we can get 100 kW electricity.

From 837,000 Bigha PKL, we can get 83,700,000 kW electricity = 83,700 MW.

The AL (agricultural land) is needed to cultivated foods and crops [81–89]. The NAL is needed for housing, roads and other multipurpose use. So that the NAL of coastal areas, hilly areas and both sides of the road can be used for cultivation of PKL to generate electricity in Bangladesh, which would be approximately 2% of NAL [90–94].

2.4 Cultivation of PKL in Bangladesh

The cultivation of PKL is so much easy [126, 127]. This plants grow whether its leaf is kept on the ground and hence can be cultivated in a vested land, roof top of the house, courtyard and tubs what so ever [115–123]. Its leaves can be used for producing electricity within a month after cultivation of the plants [65–75, 124, 125, 128, 129].

2.4.1 E significance/rationale

The significance of the work is given by the following:

i. It is renewable energy sources

ii. It is biomass energy

iii. It is environment friendly

iv. It is echo friendly

v. It is cost effective

vi. It can be cultivated by anybody

vii. Even a handicapped person can cultivate this energy

viii. Unused land can be used for this purposes

ix. The two sides of the road across the country can be used to cultivate electricity

x. The PKL tree grows everywhere even in the sand

xi. The people of the remote areas can be used this power

xii. This technology is developed locally

xiii. This technology is innovated in Bangladesh

xiv. It can compare with solar PV electricity

xv. It will not need any extra battery during night time

xvi. It will work same during day and night time

It will also work same during rainy season whereas solar PV works less during rainy season.

3. Results and discussion

3.1 Selection of electrode pair as an energy source for living PKL electricity cultivation

It is shown in **Table 1**, the collected voltage has been tabulated using different electrodes of Cu/Zn, Cu/Fe, Al/Zn and Cu/Al.

Date	Local time	Time duration (h)	Voltage (Cu/Zn) in volt	Voltage (Cu/Fe) in volt	Voltage (Al/Zn) in volt	Voltage (Cu/Al) in volt	Comments
05/10/18	08 AM	00	0.95	0.61	0.42	0.5	Single pair
Do	09 AM	1	0.95	0.61	0.41	0.50	Do
Do	10 AM	2	0.95	0.60	0.40	0.51	Do
Do	11 AM	3	0.95	0.60	0.39	0.50	Do
Do	12 PM	4	0.95	0.61	0.40	0.49	Do
Do	13 PM	5	0.95	0.60	0.39	0.48	Do
Do	14 PM	6	0.95	0.61	0.38	0.48	Do
Do	15 PM	7	0.95	0.61	0.38	0.48	Do
Do	16 PM	8	0.95	0.60	0.37	0.48	Do
Do	17 PM	9	0.95	0.61	0.36	0.48	

Table 1.
Data for voltage harvesting for single pairs of electrodes.

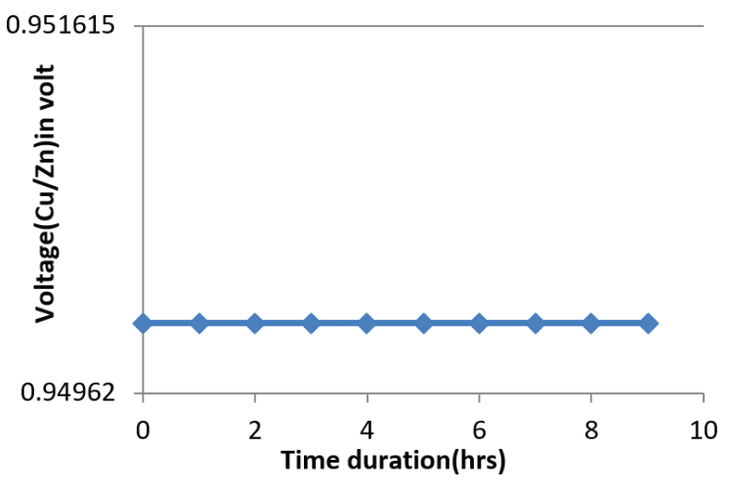


Figure 3.
Voltage-time duration profile for Cu/Zn single electrodes.

It is shown from **Figure 3**, the highest open circuit voltage (V_{oc}) for Cu/Zn single electrodes is 0.95 V and the lowest open circuit voltage (V_{oc}) is also 0.95 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is zero volt.

It is shown from **Figure 4**, the highest open circuit voltage (V_{oc}) for Cu/Fe single electrode is 0.61 V and the lowest open circuit voltage (V_{oc}) is also 0.60 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is 0.01 V.

It is shown from **Figure 5**, the highest open circuit voltage (Voc) for Al/Zn single electrodes is 0.42 V and the lowest open circuit voltage (V_{oc}) is also 0.36 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is 0.06 V.

It is shown from **Figure 6**, the highest open circuit voltage (V_{oc}) for Cu/Al single electrodes is 0.51 V and the lowest open circuit voltage (V_{oc}) is also 0.48 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is 0.03 V.

Finally, it is concluded that, **Figures 3–6** shows the variation of Voltage with the variation of time duration profile for Cu/Zn single electrodes. It is shown that the Cu/Zn single pair electrode produces the highest open circuit voltage around 0.95 V. It is also shown that it is almost constant for 9 h. Whereas the Cu/Fe, Al/Zn and

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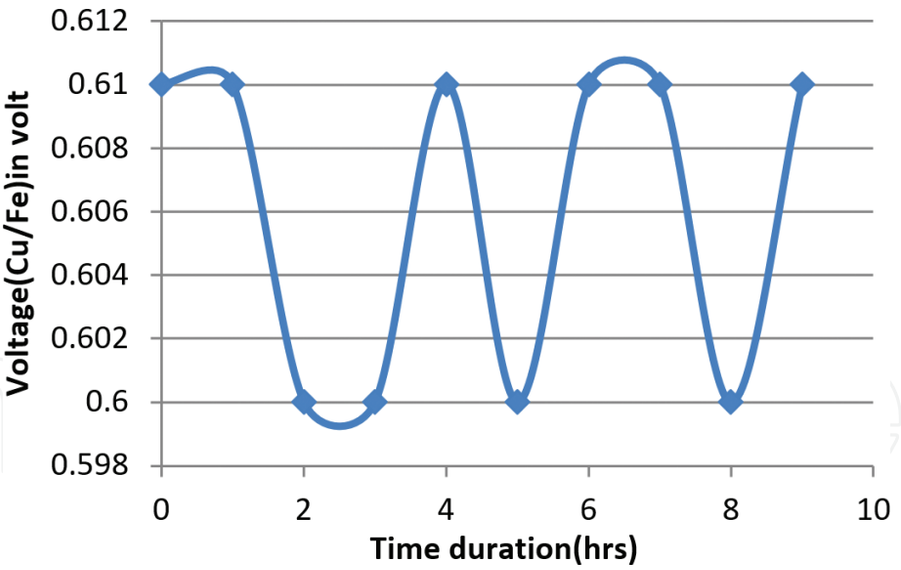


Figure 4.
Voltage-time duration profile for Cu/Fe single pair electrodes.

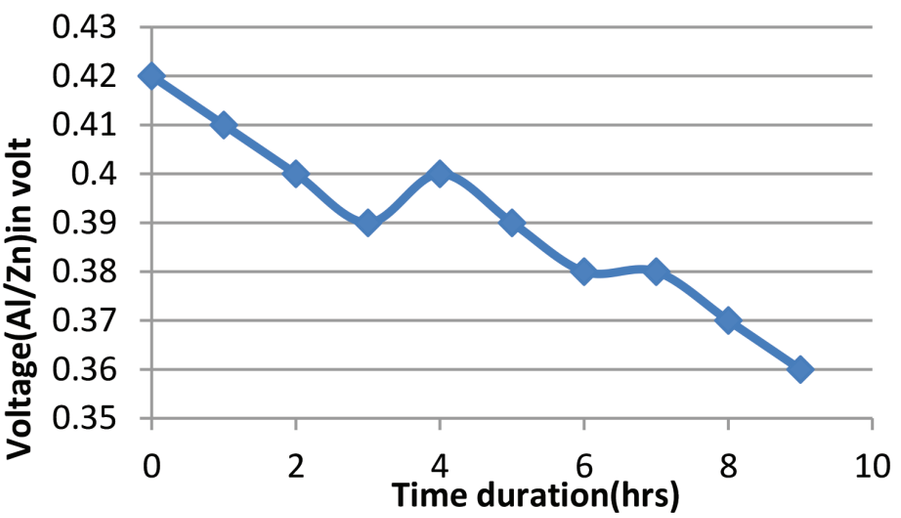


Figure 5.
Voltage-time duration profile for Al/Zn single pair electrodes.

Cu/Al producing highest open circuit voltages are 0.61, 0.42, and 0.5 V, respectively, the lowest open circuit voltages are around 0.60, 0.36, and 0.48 V, respectively. Finally, it is found and suggested that the Cu/Zn single pair electrode produces the highest open circuit voltage (V_{oc}) around 0.95 V and the Al/Zn single pair electrode-produces the lowest open circuit voltage (V_{oc}) around 0.42 V. It is also found that for Cu/Zn, Cu/Fe, Al/Zn and Cu/Al single pair electrodes, the cultivated voltage was stable up to 9 h during day time. The lowest open circuit voltage (V_{oc}) difference for Cu/Zn single pair electrodes is zero (0) V and the highest lowest open circuit voltage (V_{oc}) difference for Al/Zn single pair electrodes is 0.06 V.

It is shown in **Table 2**, the harvested voltage has been tabulated using different two pair electrodes of Cu/Zn, Cu/Fe, Al/Zn and Cu/Al with series combination.

It is shown from **Figure 7**, the highest open circuit voltage (V_{oc}) for Cu/Zn double electrodes is 1.85 V and the lowest open circuit voltage (V_{oc}) is also 1.78 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is 0.07 V. Whereas it was zero (0) for Cu/Zn single pair electrodes. The reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections.

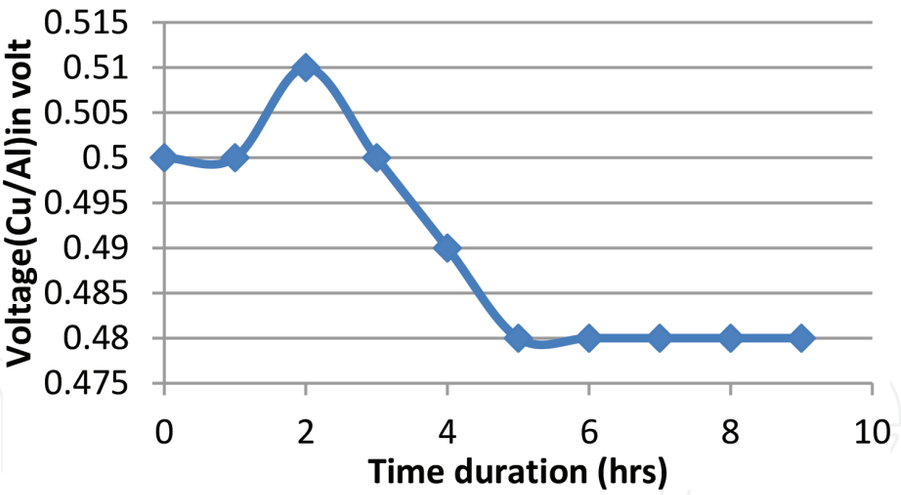


Figure 6
Voltage-time duration profile for Cu/Al single pair electrodes.

Date	Local time	Time duration (h)	Voltage (Cu/Zn) in volt	Voltage (Cu/Fe) in volt	Voltage (Al/Zn) in volt	Voltage (Cu/Al) in volt	Comments
05/10/18	08 AM	00	1.85	1.19	0.80	1.0	Two pairs
Do	09AM	1	1.84	1.20	0.81	1.0	Do
Do	10 AM	2	1.82	1.18	0.80	1.0	Do
Do	11AM	3	1.83	1.18	0.79	1.0	Do
Do	12PM	4	1.82	1.17	0.80	0.98	Do
Do	13PM	5	1.80	1.17	0.79	0.95	Do
Do	14 PM	6	1.80	1.16	0.78	0.94	Do
Do	15 PM	7	1.80	1.17	0.78	0.94	Do
Do	16 PM	8	1.80	1.17	0.77	0.94	Do
Do	17 PM	9	1.78	1.16	0.76	0.93	

Table 2.
Data for voltage harvesting for double pairs of electrodes (connected in series with each other).

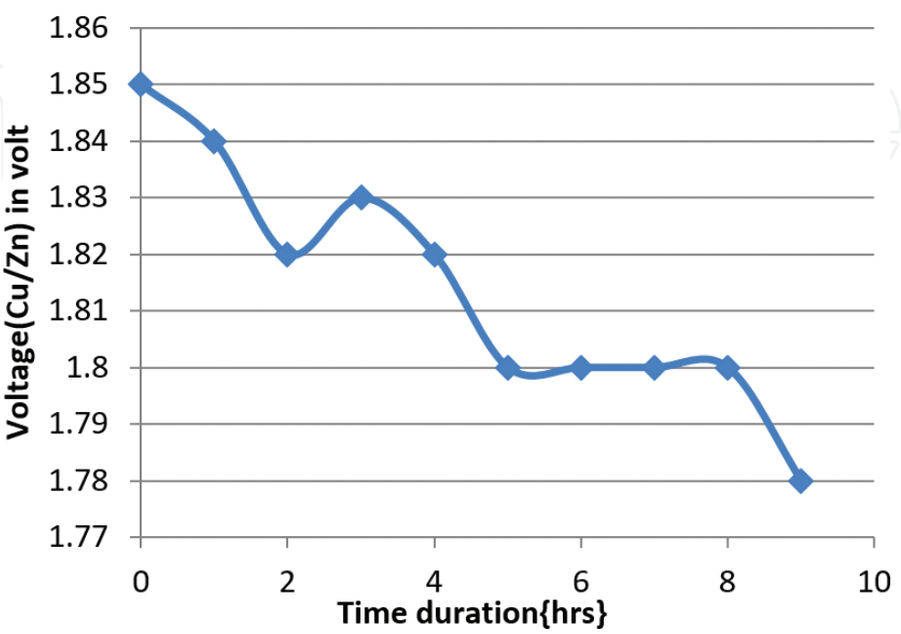


Figure 7
Voltage-time duration profile for Cu/Zn double pair electrodes.

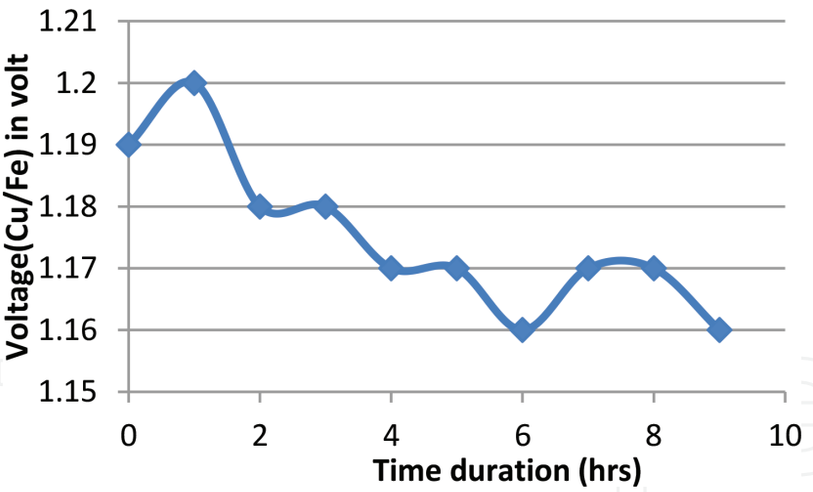


Figure 8
Voltage-time duration profile for Cu/Fe double pair electrodes.

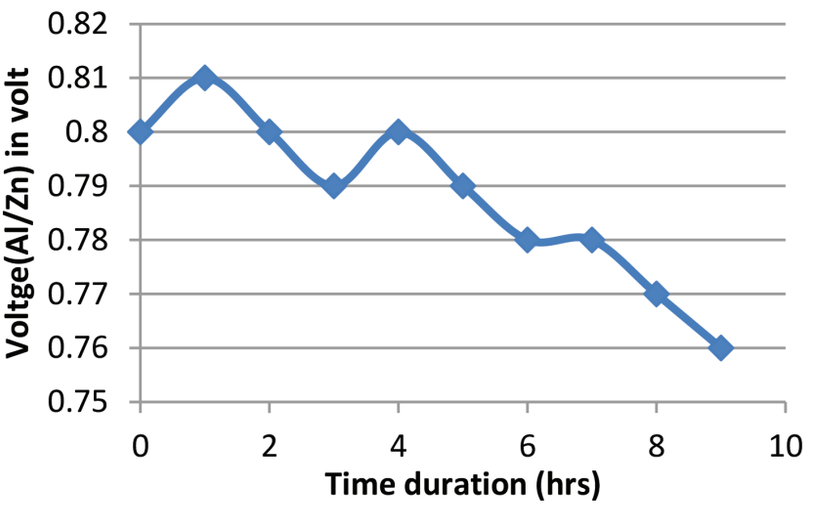


Figure 9.
Voltage-time duration profile for Al/Zn double pair electrodes.

It is shown from **Figure 8**, the highest open circuit voltage (V_{oc}) for Cu/Fe double electrodes is 1.20 V and the lowest open circuit voltage (V_{oc}) is also 1.16 V. So that the difference between the highest and lowest open circuit voltage (Voc) is 0.04 V. Whereas it was 0.01 V for Cu/Fe single pair electrodes. The reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections.

It is shown from **Figure 9**, the highest open circuit voltage (V_{oc}) for Al/Zn double electrodes is 0.81 V and the lowest open circuit voltage (V_{oc}) is also 0.76 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is 0.05 V. Whereas it was 0.04 V for Al/Zn single pair electrodes. The reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections.

It is shown from **Figure 10**, the highest open circuit voltage (V_{oc}) for Cu/Al double electrodes is 1.0 V and the lowest open circuit voltage (V_{oc}) is also 0.93 V. So that the difference between the highest and lowest open circuit voltage (Voc) is 0.07 V. Whereas it was 0.03 V for Cu/Al single pair electrodes. The reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections. From the above results it is shown that the difference between the highest and lowest voltage output increases for

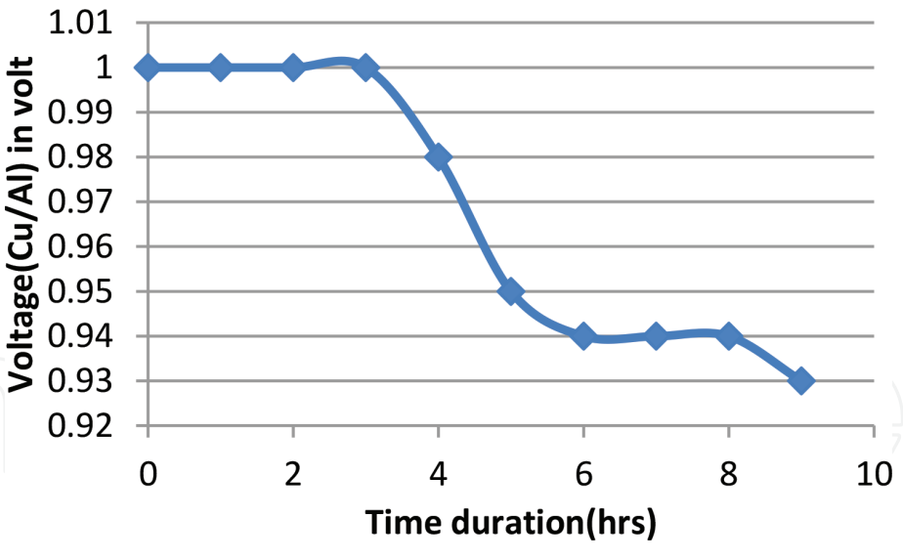


Figure 10.
Voltage-time duration profile for Cu/Al double pair electrodes.

Date	Local time	Time duration (h)	Voltage (Cu/Zn) in volt	Voltage (Cu/Fe) in volt	Voltage (Al/Zn) in volt	Voltage (Cu/Al) in volt	Comments
05/10/18	08 AM	00	2.70	1.77	1.20	0.99	Three pairs
Do	09 AM	1	2.71	1.77	1.20	0.98	Do
Do	10 AM	2	2.70	1.76	1.19	0.98	Do
Do	11 AM	3	2.69	1.76	1.19	0.98	Do
Do	12 PM	4	2.68	1.76	1.19	0.98	Do
Do	13 PM	5	2.68	1.75	1.19	0.97	Do
Do	14 PM	6	2.68	1.75	1.18	0.97	Do
Do	15 PM	7	2.68	1.75	1.18	0.97	Do
Do	16 PM	8	2.68	1.75	1.18	0.97	Do
Do	17 PM	9	2.68	1.75	1.18	0.97	

Table 3.
Data for voltage harvesting for double pairs of electrodes (connected in series with each other).

Cu/Zn, Cu/Fe, Al/Zn and Cu/Al double pair electrodes than the Cu/Zn, Cu/Fe, Al/Zn and Cu/Al single pair electrodes.

It is shown in **Table 3**, the harvested voltage has been tabulated using different three pair electrodes of Cu/Zn, Cu/Fe, Al/Zn and Cu/Al with series combination.

It is shown from **Figure 11**, the highest open circuit voltage (V_{oc}) for Cu/Zn 3-electrodes is 2.70 V and the lowest open circuit voltage (V_{oc}) is also 2.68 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is 0.02 V. Whereas it was zero (0) for Cu/Zn single pair electrodes and 0.07 V for double electrodes respectively. The same reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections.

It is shown from **Figure 12**, the highest open circuit voltage (V_{oc}) for Cu/Fe three electrodes pair is 1.77 V and the lowest open circuit voltage (V_{oc}) is also 1.75 V. So that the difference between the highest and lowest open circuit voltage (V_{oc}) is

0.02 V. Whereas it was zero (0) for Cu/Fe single pair electrodes, 0.04 V for double electrodes respectively. The same reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections.

It is shown from **Figure 13**, the highest open circuit voltage (V_{oc}) for Al/Zn 3-electrodes pair is volt and the lowest open circuit voltage (V_{oc}) is also 1.65 V. So that the difference between the highest and lowest open circuit voltage (Voc) is 0.02 V. Whereas it was zero(0) for Cu/Fe single pair electrodes and 0.04 V for double electrodes respectively. The same reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections.

It is shown from **Figure 14**, the highest open circuit voltage (V_{oc}) for Cu/Al three electrodes pair is volt and the lowest open circuit voltage (V_{oc}) is also 1.65 V.

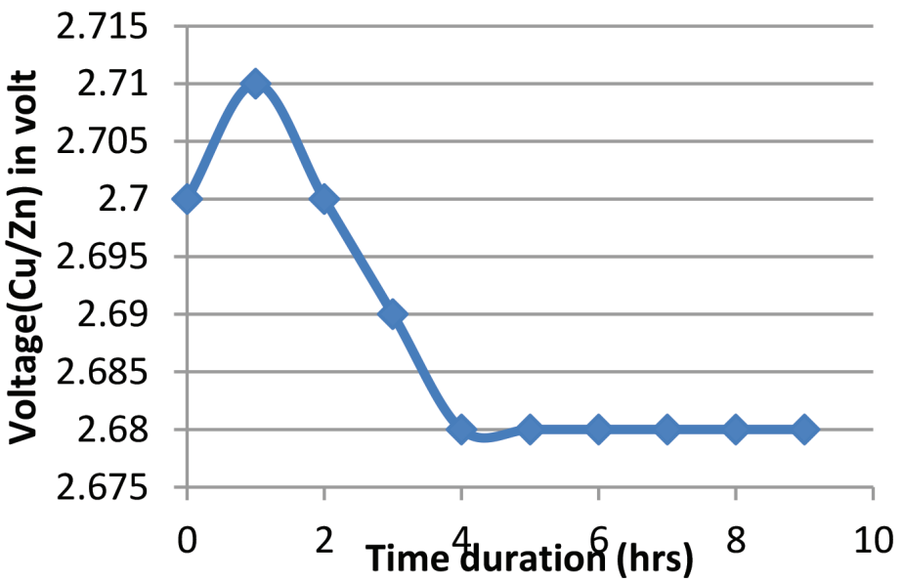


Figure 11.
Voltage-time duration profile for Cu/Zn three pair electrodes.

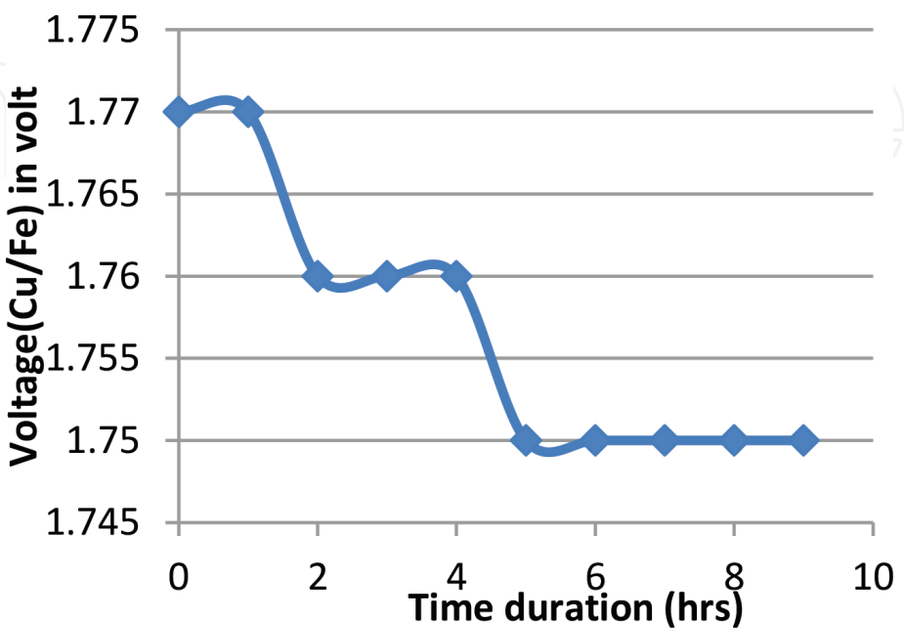


Figure 12.
Voltage-time duration profile for Cu/Fe three pair electrodes.

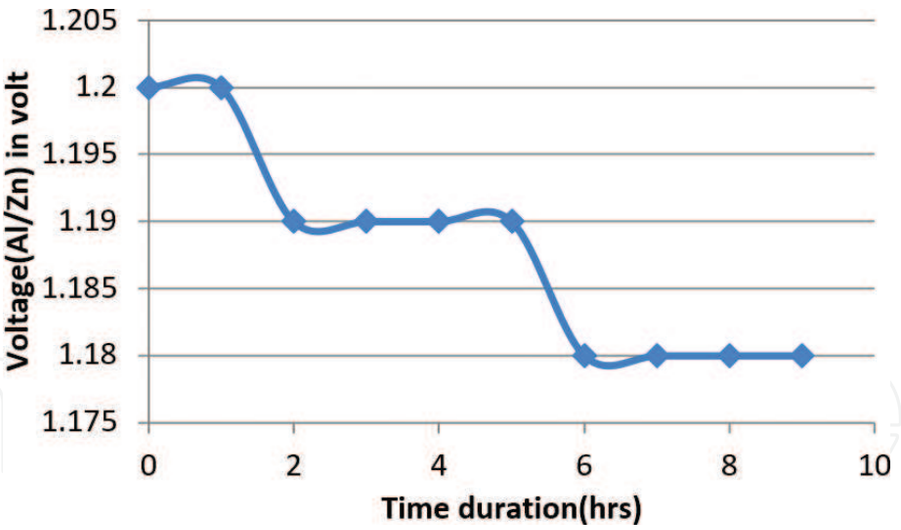


Figure 13.
Voltage-time duration profile for Al/Zn three pair electrodes.

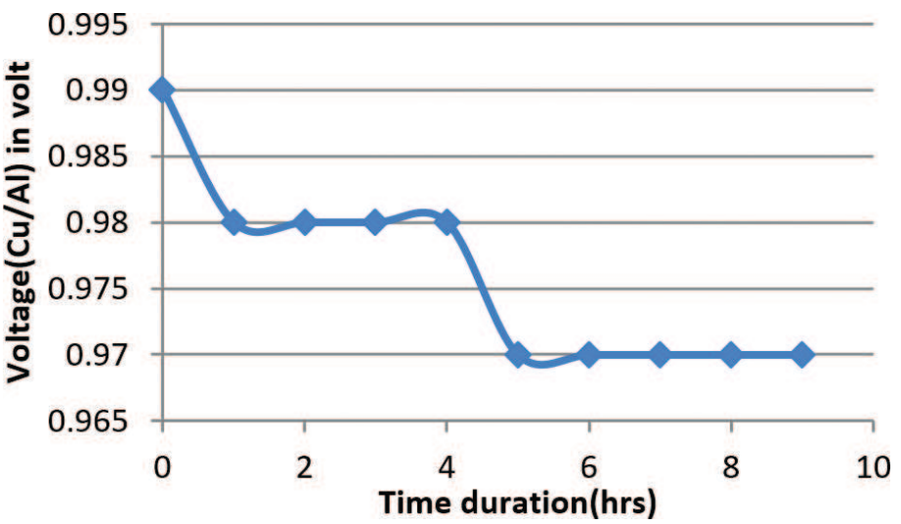


Figure 14.
Voltage-time duration profile for Cu/Al three pair electrodes.

So that the difference between the highest and lowest open circuit voltage (V_{oc}) is 0.02 V. Whereas it was zero (0) for Cu/Al single pair electrodes, 0.04 V for double electrodes and 0.02 V, respectively. The same reason behind it is that due to the connection of the electrodes by the wires, because it grows resistance for long wires due to the connections.

It is shown in **Table 4**, the voltage difference for Cu/Zn, Cu/Fe, Al/Zn and Cu/Al single, double and triple electrodes in volt.

3.2 Electrochemical cell made by two living PKL trees

3.2.1 Description of the electrodes

1. Description of the cathode

The length of the copper electrode is: 3 cm

The breadth of the copper electrode is: 1 cm

Number of pairs	Voltage difference for Cu/Zn in volt	Voltage difference for Cu/Fe in volt	Voltage difference for Al/Zn in volt	Voltage difference for Cu/Al in volt
1	0	0.01	0.60	0.02
2	0.07	0.03	0.05	0.07
3	0.03	0.02	0.02	0.03

Table 4.
Table for voltage difference for Cu/Zn, Cu/Fe, Al/Zn and Cu/Al in volt.

The area of the copper electrode is: (3 cm) (1 cm) = 3 cm^2

2. Description of the anode

The length of the zinc electrode is: 3 cm

The breadth of the zinc electrode is: 1 cm

The area of the zinc electrode is: (3 cm) (1 cm) = 3 cm^2

3.2.2 Description of the electrolytes

It was taken two living PKL plants (Tree-1 and Tree-2) for making an electrochemical cell. One leaf was selected from each tree. Each leaf was embedded by two electrodes. The voltage was collected from each leaf separately by a sophisticated multi meter. Then it was connected two living PKL plants in series connection. Then after the voltage was also collected for series connection.

4. Results and discussion

It is shown in **Figure 15** the variation of open circuit voltage with the variation of time duration(hr) for a single leaf in tree-1. Similarly, **Figure 16** the variation of open circuit voltage with the variation of time duration(hr) for a single leaf in tree-2. Finally, it is shown in **Figure 17** the variation of open circuit voltage with the variation of time duration (h) for both a single leaf in tree-1and tree-2. Comparing

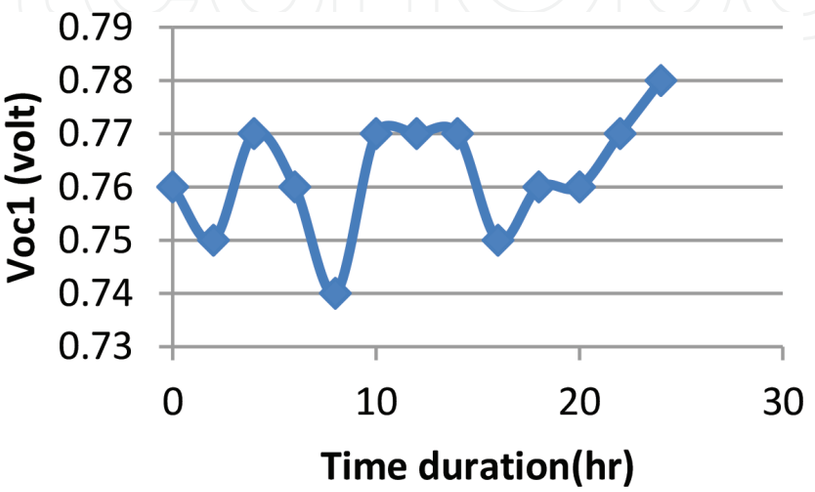


Figure 15.
Voc1-time duration curve for tree-1.

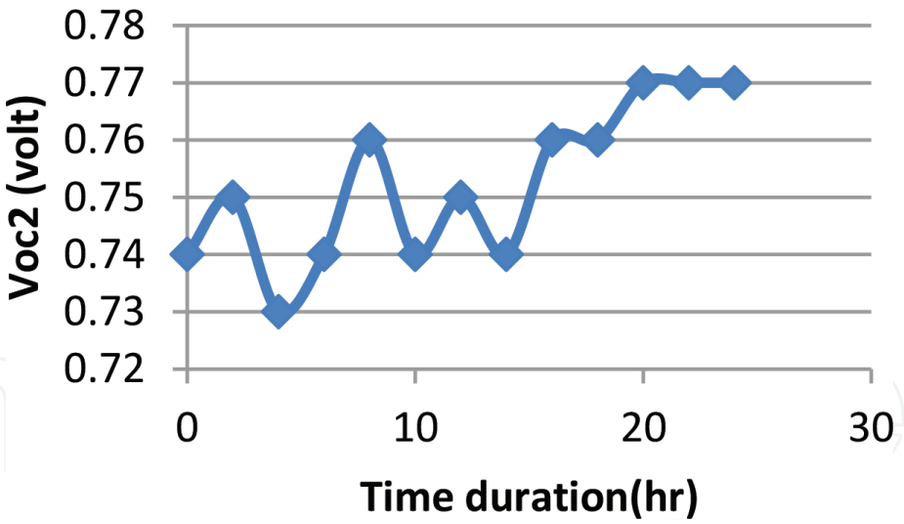


Figure 16.
Voc2-time duration curve for tree-2.

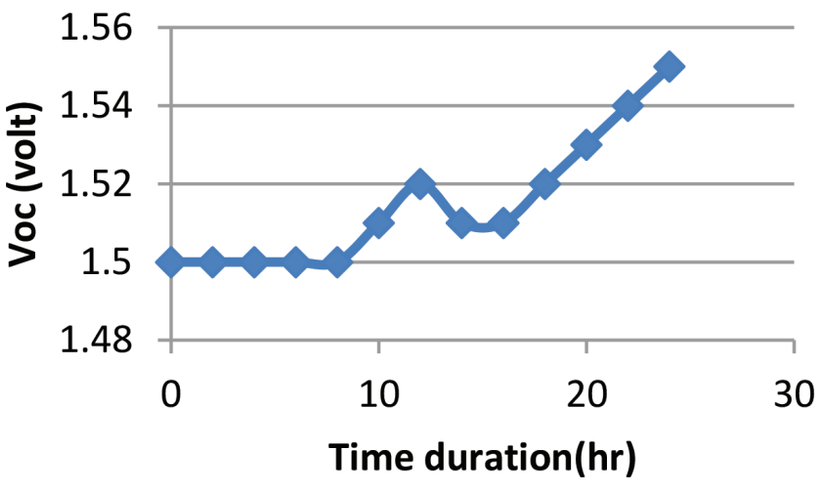


Figure 17.
Voc-time duration for both tree-1 and tree-2 in series connection.

above three figures, it can be concluded that living PKL tree can generate an electrochemical cell, since it follows the law of the series combination of voltaic cell.

5. Conclusion

The multi meters which were used are not calibrated properly. So that may be some errors during collection of the readings. In spite of that the authors tried to take readings very carefully. At present it is needed renewable, sustainable, pollution free and an efficient energy sources all over the world. To keep it in mind, it has been introduced some fundamental investigations are presented for producing electricity from living PKL plants. The power is produced by embedding the different electrodes like (silver and zinc, copper and zinc, etc.) and cells into the PKL living plant's leaf to allow flow of ions using redox reaction. Different experiments have been conducted using different types of the electrodes to determine the characteristics of the producing device. The research activities in this field are in infancy, in spite of that it was possible to get voltage difference around 1.10 V using single pair of electrodes and cell. Such hypothesis has been tested at different times

of the different month of the year. A comparative research works have also been done and used in combination to get better results for the development of such a green power. This green power may be the guide line to get low and medium power electrical and electronic appliances in near future.

Sustainable energy sources, which are pollution free and environmentally friendly, are one of the key challenges of world's future society. The interdisciplinary team of PKL energy foundation discovered that living plants are literally "green" power source, which may become one of future's electricity supplies that perfectly integrates in natural environments and is accessible all over the world. Researchers discovered that living plants can generate, by a single leaf, required Volts, enough to simultaneously power LED light bulbs. Researchers also showed that natural leaves can act as an innovative "green" electrical generator converting into electricity. Finally, the outcome of this research work is the reactant and product ions have been identified. The generated voltage can be considered with the Nernst equation. The generated voltage can be connected in series to run the load with LED bulb and DC fan. Using an inverter can be converted AC from DC for AC appliances.

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References

[1] Akter T, Bhuiyan MH, Khan KA, Khan MH. Impact of photo electrode thickness and annealing temperature on natural dye sensitized solar cell. Sustainable Energy Technologies and Assessments. 2017 Ms. Ref. No.: SETA-D-16-00324R2

[2] Guha B, Islam F, Khan KA. Studies on redox equilibrium and electrode potentials. IJARIIE. 2018;**4**(4):1092-1102

[3] Hamid MR. Characterization of a battery cell fueled by *Bryophyllum pinnatum* sap. International Journal of Scientific and Engineering Research. 2013;**4**(3):1-4

[4] Hamid MR, Yusuf A, Wadud AMA, Rahaman MM. Design and performance test of a prototype of a 12 V dc battery fueled by *Bryophyllum pinnatum* sap and improvement of its characteristics. International Journal of Electrical and Electronics Engineering. 2016;**4**(5):1-5

[5] Haque MM, Ullah AKMA, Khan MNL, Kibria AKMFF, Khan KA. Phyto-synthesis of MnO_2 nanoparticles for generating electricity. In: The International Conference on Physics-2018, Venue-Department of Physics, University of Dhaka, Dhaka 1000, Bangladesh, Organizer-Bangladesh Physical Society (BPS), 08–10 March. 2018

[6] Hasan M, Khan KA. *Bryophyllum pinnatum* leaf fueled cell: An alternate way of supplying electricity at the off-grid areas in Bangladesh. In: Proceedings of 4th International Conference on the Developments in Renewable Energy Technology [ICDRET 2016]. 2016, 2016. p. 01. DOI: 10.1109/ICDRET.2016.7421522

[7] Hasan M, Khan KA. Dynamic model of *Bryophyllum pinnatum* leaf fuelled BPL cell: A possible alternate source of electricity at the off-grid region in Bangladesh. Microsystem Technologies. 2018. DOI: 10.1007/s00542-018-4149-y

[8] Hasan M, Khan KA. Identification of BPL cell parameters to optimize the output performance for the off-grid electricity production. In: International Conference on Physics-2018, Venue-Department of Physics, University of Dhaka, Dhaka 1000, Bangladesh, Organizer-Bangladesh Physical Society (BPS), 08–10 March. 2018

[9] Hasan M, Haque S, Khan KA. An experimental study on the coulombic efficiency of *Bryophyllum pinnatum* leaf generated BPL cell. IJARIIE. 2016;**2**(1):1-9

[10] Hasan MM, Khan MKA, Khan MNR, Islam MZ. Sustainable electricity generation at the coastal areas and the islands of Bangladesh using biomass resources. City University Journal. 2016;**02**(01):09-13

[11] Hasan M, Hassan L, Haque S, Rahman M, Khan KA. A study to analyze the self-discharge characteristics of *Bryophyllum pinnatum* leaf fueled BPL test cell. IJRET. 2017;**6**(12):6-12

[12] Hasan M, Khan KA, Mamun MA. An estimation of the extractable electrical energy from *Bryophyllum pinnatum* leaf. American International Journal of Research in Sciences, Technology, Engineering and Mathematics. 2017;**01**(19):100-106

[13] Hasan L, Hasan M, Khan KA, Islam SMA. SEM analysis of electrodes and measurement of ionic pressure by AAS data to identify and compare the characteristics between different biofuel based electrochemical cell. In: International Conference on

Physics-2018, Venue-Department of Physics, University of Dhaka, Dhaka-1000, Bangladesh, Organizer-Bangladesh Physical Society (BPS), 08–10 March. 2018

[14] Hassan MM, Arif M, Khan KA. Modification of germination and growth patterns of *Basella alba* seed by low pressure plasma. Journal of Modern Physics.: Paper ID 7503531. 2018:97-104

[15] Hossain MA, Khan MKA, Quayum ME. Performance development of bio-voltaic cell from arum leaf extract electrolytes using Zn/Cu electrodes and investigation of their electrochemical performance. International Journal on Advanced Science, Engineering and Information Technology. 2017;**5**(4)

[16] Islam F, Guha B, Khan KA. Studies on pH of the PKL extract during electricity generation for day and night time collected Pathor Kuchi leaf. IJARIIE. 2018;**4**(4):1102-1113

[17] Khan MKA. Copper oxide coating for use in linear solar Fresnel reflecting concentrating collector. Journal of Renewable Energy. 1998 RE: 12.97/859

[18] Khan KA. Technical note "Copper oxide coatings for use in a linear solar Fresnel reflecting concentrating collector". Journal of Renewable Energy. 1999;**17**(4):603-608

[19] Khan KA. Inventors, electricity generation form Pathor Kuchi Leaf (PKL). Publication date 2008/12/31. Patent number BD 1004907; 2008

[20] Khan KA, Rasel SR, Ohiduzzaman M. Homemade PKL electricity generation for use in DC fan at remote areas. Microsystem Technologies. Springer, MITE-D-19-00131, 2019. Accepted

[21] Khan KA. Electricity generation form Pathor Kuchi leaf (*Bryophyllum pinnatum*). International Journal of Sustainable Agricultural Technology. 2009;**5**(4):146-152

[22] Khan MKA. An experimental observation of a PKL electrochemical cell from the power production view point. In: Presented as an Invited Speaker and Abstract Published in the Conference on Weather Forecasting & Advances in Physics, 11–12 May 2018; Khulna, Bangladesh: Department of Physics, Khulna University of Engineering and Technology (KUET). 2018. pp. 75-90

[23] Khan KA, Alam MM. Performance of PKL (Pathor Kuchi Leaf) electricity and its uses in Bangladesh. International Journal of Society Development Information System. 2010;**1**(1):15-20

[24] Khan KA, Arafat ME. Development of portable PKL (Pathor Kuchi Leaf) lantern. International Journal of Society Development Information System. 2010;**1**(1):15-20

[25] Khan KA, Bosu R. Performance study on PKL electricity for using DC fan. International Journal of Society Development Information System. 2010;**1**(1):27-30

[26] Khan KA, Hossain MI. PKL electricity for switching on the television and radio. International Journal of Society Development Information System. 2010;**1**(1):31-36

[27] Khan KA, Paul S (2013) A analytical study on electrochemistry for PKL (Pathor Kuchi Leaf) electricity generation system. In: Publication Date 2013/5/21, Conference-Energytech, 2013. IEEE Publisher, IEEE. pp. 1-6

[28] Khan KA, Hossain A. Off-grid 1 KW PKL power technology: design, fabrication, installation and operation. In: Proceedings of CCSN-2018, 27–28 October, 2018 at Kolkata, India. 2018

[29] Khan MKA, Obaydullah AKM. Construction and commercial use of PKL cell. IJARIIE. 2018;**4**(2): 3563-3570

[30] Khan DMKA. Prospect of solar energy for food supply in Bangladesh. Bangladesh Journal of Scientific and Industrial Research. 2002; **37**:1-4

[31] Khan A, Abu Salek M. A study on research, development and demonstration of renewable energy technologies, IJARIIE. 2019;**5**(4): 113-125

[32] Ahsan MN, Sen BK, Khan KA, Hamid Khan MA. Performance of a low cost built-in-storage solar water heater. Nuclear Science and Applications. 1999; **8**:1-2

[33] Khan AJ, Khan KA, Mahmood ZH, Hossain M. Performance of an intermittently tracked linear solar Fresnel reflecting concentrator. The Dhaka University Studies, Part B (Science). 1991;**39**(2)

[34] Khan KA, Khan AJ, Rabbani KS. Design & performance studies of a linear Fresnel reflecting solar concentrator-receiver system. Bangladesh Journal of Scientific Research. 1998;**16**(2):143-146

[35] Khan MKA. Studies on electricity generation from stone chips plant (*Bryophyllum pinnatum*). International Journal of Engineering & Technology. 2008;**5**(4):393-397

[36] Khan MKA. Solar selective coating for use in solar concentrating collector. Bangladesh Journal of Scientific Research. 1998;**16**(2):249-252

[37] Khan MKA. The performance of a Fresnel reflecting concentrating collector with auxiliary heating. Bangladesh Journal of Scientific and Industrial Research. 1999;**34**(2)

[38] Khan MKA. Production of candles by solar system in Bangladesh. Nuclear Science & Applications. 1998;**7**(1,2)

[39] Khan KA, Yesmin F, Wadud MA, Obaydullah AKM. Performance of PKL electricity for use in television. In: International Conference on Recent Trends in Electronics & Computer Science-2019, Venue: NIT Silchar, Assam, India, Conference date: 18th and 19th of March, 2019. Organizer: Department of Electronics and Engineering, NIT Silchar, Assam, India. 2019. p. 69

[40] Mamun MA, Ibrahim M, Shahjahan M, Khan KA. Electrochemistry of the PKL electricity. In: International Conference on Recent Trends in Electronics & Computer Science-2019, Venue: NIT Silchar, Assam, India, Conference date: 18th and 19th of March, 2019. Organizer: Department of Electronics and Engineering, NIT Silchar, Assam, India. 2019. p. 71

[41] Khan KA, Hossain MA, Kabir MA, Rahman MA, Lipe P. A study on performance of ideal and non-ideal solar cells under the climatic situation of Bangladesh. International Journal of Advance Research And Innovative Ideas in Education. 2019;**5**(2):975-984

[42] Hassan L, Khan KA. A study on harvesting of PKL electricity, microsystem technologies. 2019. DOI: 10.1007/s00542-019-04625-7

[43] Hassan SJ, Khan KA. Design, fabrication and performance study of bucket type solar candle machine. Int. J. Eng. Trach. 2007, 2007;**4**(3). Website: www.Gsience.Net

[44] Khan MA, Hamid Khan DMKA. Nuclear Science and Applications. June 2005;**14**(11)

[45] Khan KA, Rasel SR. Prospects of renewable energy with respect to energy reserve in Bangladesh. IJARII. 2018;**4** (5):280-289

[46] Khan KA, Rasel SR. Studies on wave and tidal power extraction devices. International Journal of Advance Research and Innovative Ideas in Education. 2018;**4**(6):61-70

[47] Khan KA, Yesmin F. PKL electricity —A step forward in clean energy. International Journal of Advance Research and Innovative Ideas in Education. 2019;**5**(1):316-325

[48] Khan KA, Paul S, Adibullah M, Alam MF, Sifat SM, Yousufe MR. Performance analysis of BPL/PKL electricity module. International Journal of Scientific and Engineering Research. 2013;**4**(3):1-4

[49] Khan KA, Paul S, Zobayer A, Hossain SS. A study on solar photovoltaic conversion. International Journal of Scientific and Engineering Research. 2013;**4**(3):1-6

[50] Khan KA, Bakshi MH, Mahmud AA. *Bryophyllum pinnatum* leaf (BPL) is an eternal source of renewable electrical energy for future world. American Journal of Physical Chemistry. 2014;**3**(5):77-83. DOI: 10.11648/j.ajpc.20140305.15

[51] Khan KA, Alam MS, Mamun MA, Saime MA, Kamal MM. Studies on electrochemistry for Pathor Kuchi leaf power system. Journal of Agricultural and Environmental Sciences. 2016;**12**(1):37-42

[52] Khan KA, Rahman A, Rahman MS, Tahsin A, Jubyer KM, Paul S. Performance analysis of electrical parameters of PKL electricity (an experimental analysis on discharge rates, capacity and discharge time, pulse performance and cycle life and deep discharge of Pathor Kuchi Leaf (PKL) electricity cell). In: IEEE Innovative Smart Grid Technologies-Asia (ISGT-Asia). 2016, 2016. pp. 540-544

[53] Khan MKA, Paul S, Rahman MS, Kundu RK, Hasan MM, Moniruzzaman M, et al. A study of performance analysis of PKL electricity generation parameters: (an experimental analysis on voltage regulation, capacity and energy efficiency of Pathor Kuchi leaf (PKL) electricity cell). In: 2016 IEEE 7th Power India International Conference (PIICON). 2016. pp. 1-6

[54] Khan MKA, Rahman MS, Das T, Ahmed MN, Saha KN, Paul S. Investigation on parameters performance of Zn/Cu electrodes of PKL, AVL, tomato and lemon juice based electrochemical cells: A comparative study. In: 2017 3rd International Conference on Electrical Information and Communication Technology (EICT) IEEE, 2017. IEEE, Khulna, Bangladesh, Bangladesh. 2017. pp. 1-6. DOI: 10.1109/EICT.2017.8275150

[55] Khan KA, Ali MH, Mamun MA, Haque MM, Ullah AKMA, Khan MNI, et al. Bioelectrical characteristics of Zn/Cu-PKL cell and production of nanoparticles (NPs) for practical utilization. In: 5th International Conference on 'Microelectronics, Circuits and Systems', Micro 2018, 19th and 20th May, 2018, In Association with: International Association of Science, Technology and Management. 2018. pp. 59-66. Available from: http://www.actsoft.org

[56] Khan KA, Ali MH, Mamun MA, Ibrahim M, Obaidullah AKM, Hossain MA, et al. PKL electricity in mobile technology at the off-grid region. In: Published in the Proceedings of CCSN-2018, 27–28 October, Kolkata, India. 2018. p. 57

[57] Khan KA, Ahmed SM, Akhter MM, Alam R, Hossen M. Wave and tidal power generation. International Journal of Advance Research and Innovative Ideas in Education. 2018;**4**(6):71-82

[58] Khan KA, Bhuyan MS, Mamun MA, Ibrahim M, Hassan L, Wadud MA. Organic electricity from Zn/Cu-PKL electrochemical cell. Advances in Intelligent Systems and Computing. 2018. DOI: 10.1007/978981-13-1540-4

[59] Khan KA, Bhuyan MS, Mamun MA, Ibrahim M, Hassan L, Wadud MA. Organic electricity from Zn/Cu-PKL electrochemical cell. In: Published in the Souvenir of First International Conference of Contemporary Advances in Innovative & Information Technology (ICCAIAIT) 2018, Organized by KEI, in collaboration with Computer Society of India (CSI), Division IV (Communication). 2018. The proceedings consented to be published in AISC Series of Springer

[60] Khan KA, Hassan L, Obaydullah AKM, Islam SA, Mamun MA, Akter T, et al. Bioelectricity: A new approach to provide the electrical power from vegetative and fruits at off-grid region. Journal of Microsystem Technology. 2018;**24**(3):2. DOI: 10.1007/s00542018-3808-3

[61] Khan KA, Hasan M, Islam MA, Alim MA, Asma U, Hassan L, et al. Astudy on conventional energy sourcesfor power production. InternationalJournal of Advance Research andInnovative Ideas in Education. 2018;**4**(4):214-228

[62] Khan KA, Hossain MS, Kamal MM, Rahman MA, Miah I. Pathor Kuchi leaf: Importance in power production. IJARIIE. 2018;**4**(5)

[63] Khan KA, Hossain MA, Obaydullah AKM, Wadud MA. PKL electrochemical cell and the Peukert's law. IJARIIE. 2018;**4**(2):4219-4227

[64] Khan KA, Mamun MA, Ibrahim M, Hasan M, Ohiduzzaman M, Obaidullah AKM, et al. PKL electrochemical cell for off-grid areas: Physics, chemistry and technology. In: Proceedings of CCSN-2018, 27–28 October, 2018 at Kolkata, India. 2018

[65] Khan KA, Manir SMM, Islam MS, Jahan S, Hassan L, Ali MH. Studies on nonconventional energy sources for electricity generation. International Journal of Advance Research and Innovative Ideas in Education. 2018;**4**(4):229-244

[66] Khan KA, Miah MS, Ali MI, Sharma SK, Quader A. Studies on wave and tidal power converters for power production. International Journal of Advance Research and Innovative Ideas in Education. 2018;**4**(6):94-105

[67] Khan MKA, Obaydullah AKM, Wadud MA, Hossain MA. Bi-product from bioelectricity. IJARIIE. 2018;**4**(2): 3136-3142

[68] Khan KA, Rahman ML, Islam MS, Latif MA, Khan MAH, Saime MA, et al. Renewable energy scenario in Bangladesh. IJARII. 2018;**4**(5):270-279

[69] Khan KA, Rahman MA, Islam MN, Akter M, Islam MS. Wave climate study for ocean power extraction. International Journal of Advance Research and Innovative Ideas in Education. 2018;**4**(6):83-93

[70] Khan KA, Wadud MA, Hossain MA, Obaydullah AKM. Electrical performance of PKL (Pathor Kuchi leaf) power. IJARIIE. 2018;**4**(2):3470-3478

[71] Khan KA, Wadud MA, Obaydullah AKM, Mamun MA. PKL (*Bryophyllum pinnatum*) electricity for practical utilization. IJARIIE. 2018;**4**(1): 957-966

[72] Paul S, Khan KA, Islam KA, Islam B, Reza MA. Modeling of a biomass energy based (BPL) generating power plant and its features in comparison with other generating plants. IPCBEE. 2012. DOI: 10.7763/ IPCBEE.2012.V44.3

[73] Ruhane TA, Islam MT, Rahaman MS, Bhuiyan MMH, Islam JMM, Newaz MK, et al. Photo current enhancement of natural dye sensitized solar cell by optimizing dye extraction and its loading period. Optik. 2017;**149**:174-183

[74] Sultana J, Khan KA, Ahmed MU. Electricity generation from Pathor Kuchi Leaf (PKL) (*Bryophyllum pinnatum*). Journal of the Asiatic Society of Bangladesh, Science. 2011;**37**(4): 167-179

[75] Khan KA, Yesmin F. Cultivation of electricity from living PKL tree's leaf. International Journal of Advance Research and Innovative Ideas in Education. 2019;**5**(1):462-472

[76] Khan MKA. Field testing of a Fresnel reflecting solar concentrator. Nuclear Science & Applications. 1997;**6**(1,2)

[77] Khan MKA, Khan AJ, Rabbani KS. Solar thermal steam production & distillation device by Fresnel reflecting concentrator-receiver system. Bangladesh Journal of Scientific Research. 1998;**16**(2):221-228

[78] Islam MS, Khan MKA. Performance studies on single crystal solar PV modules for practical utilisation in Bangladesh. International Journal of Engineering & Technology. 2008;**5**(3): 348-352

[79] Khan MKA. Studies on fill factor (FF) of single crystal solar PV modules for use in Bangladesh. International Journal of Engineering & Technology. 2008;**5**(3):328-334

[80] Khan MKA. Performance studies of monocrystallinne PV module considering the shadow effect. International Journal of Engineering & Technology. 2008;**5**(3):342-347

[81] Islam MS, Khan MKA. Study the deterioration of a monocrystal solar silicon PV module under Bangladesh climate. International Journal of Engineering & Technology. 2008;**5**(2): 263-268

[82] Hassan SJ, Khan MKA. Design, fabrication and performance study of a single phase inverter for use in solar PV system. International Journal of Engineering & Technology. March 2008;**5**(1):212-216

[83] Khan DMKA. Soap production using solar power. International Journal of Engineering & Technology. 2009;**6**(1): 414-419. Website: www.gscience.net

[84] Khan DMKA. Wave and tidal power generation: An overview. International Journal of Engineering & Technology. 2009;**6**(1):420-423. Website: www.gscience.net

[85] Khan DMKA. Materials used in electricity generation by solar thermal system. International Journal of Engineering & Technology. 2009; **6**(1):515-520. Website: www. gscience.net

[86] Khan DMKA. Comparative study on single crystal and polycrystalline solar PV modules for use in Bangladesh climate. International Journal of Engineering & Technology. 2009;**6**(1): 527-529. Website: www.gscience.net

[87] Khan DMKA. Solar thermal studies of open sun drying (OSD) of various crops under Bangladesh climatic condition. International Journal of Sustainable Agricultural Technology. 2009;**5**(7):85-94

[88] Khan DMKA. An investigation on various solar cells under the climatic condition of Bangladesh. International Journal of Engineering & Technology. 2009;**6**(3):547-551

[89] Khan DMKA, Islam MS. Studies on performance of solar photovoltaic system under the climate condition of

Bangladesh. Int. J. Soc. Dev. Inf. Syst. 2010;**1**(1):37-43

[90] Khan A, Zerin N, Noman Chy SM, Nurul Islam M, Bhattacharjee R. A study on voltage harvesting from PKL living plant. IJARIIE. 2019;**5**(5):407-415

[91] Saifuddin SM, Khan DMKA. Performance study of hybrid SPV, ST and BPL/PKL electricity generation and storage for practical utilization in Bangladesh. International Journal of Engineering & Technology. 2010;**7**(2). ISSN 1812-7711

[92] Saifuddin SM, Khan DMKA. Survey of hybrid solar photovoltaic (SPV) and solar thermal (ST) collectors in Bangladesh. International Journal of Engineering & Technology. 2010;**7**(3). ISSN 1812-7711

[93] Khan KA, Rasel SR. A study on electronic and ionic conductor for a PKL electrochemical cell. IJARIIE. 2019;**5**(2): 3100-3110

[94] Sultana Jesmin KKA, Ahmed MU. Present situation of solar photovoltaic system in different countries. ASA University Review. 2010;**4**(2). ISSN: 1997-6925

[95] Rahman AA, Khan DMKA. The present situation of the wave energy in some different countries of the world. IJCIT. 2010 ISSN 2078 5828(print), ISSN2218-5224(online),2(1),Manuscript code:110754

[96] Hasnat A, Ahmed P, Rahman M, Khan KA. Numerical analysis for thermal design of a paraboloidal solar concentrating collector. International Journal of Natural Sciences. 2010, 2011; **1, 68**(3):74

[97] Khan DMKA, Rubel AH. Simulated energy scenarios of the power sector in Bangladesh. ASA University Review. 2011;**592**:101-110. ISSN: 1997-6925

[98] Sultana J, Khan MKA, Ahmed MU. Electricity generation from Pathor Kuchi Leaf (*Bryophyllum pinnatum*). Journal of the Asiatic Society of Bangladesh, Science. 2011;**37** (2):167-179

[99] Rashid MA, Mamun RA, Sultana J, Hasnat A, Rahman M, Khan KA. Evaluating the solar radiation system under the climatic condition of Bangladesh and computing the Angstrom coefficients. International Journal of Natural Sciences. 2012;**2**(1): 38-42. Received: November 2011, Accepted: March 28

[100] Sultana J, Khan KA, Mesbah Uddin Ahmed MU. The present situation of solar thermal energy in the world. ASA University Review. 2012;**4**(2). ISSN: 1997-6925

[101] Khan KA, Shatter MA, Paul S, Zishan SR, Yousufe MR. A study on tidal power conversion for use in Bangladesh. International Journal of Scientific and Engineering Research. 2012;**3**(12). ISSN 2229-5518

[102] Bhuiyan MSA, Khan KA, Jabed MA. A computerized study on the metrological parameter conversions for rural agribusiness development. Journal of Innovation & Development Strategy. 2012;**6**(2):94-98

[103] Khan DMKA, Paul S, Zobayer A, Hossain SS. A study on solar photovoltaic conversion. International Journal of Scientific and Engineering Research. 2013, 2013;**4**(3). ISSN 2229-5518 (Impact Factor: 1.4)

[104] Khan DMKA, Paul S, Zobayer A, Hossain SS. A study on solar thermal conversion. International Journal of Scientific and Engineering Research. 2013; **4**(3). ISSN 2229-5518 (Impact Factor: 1.4)

[105] Bhuiyan MSA, Khan KA. Software development studies on the metrological conversions for local agri-business units

of area and volume weight measures. Journal of Innovation & Development Strategy (JIDS) Canada. 2013;7(1). ISSN 1997-2571

[106] Ahsan MN, Kumar S, Khan MKA, Khanam MN, Khatun R, Akter S, et al. Study of spatial resolution of a positron emission tomography (PET) system. Jagannath University Journal of Science. 2013;**2**(1). ISSN 2224-1698

[107] Paul S, Khan KA, Kundu RK. Design, fabrication and performance analysis of solar inverter. In: Published in the Proceedings of IEEE, ENERGYTECH, USA, Participated and Presented in the "EnergyTech2013" Conference sponsored by the Institute of Electrical and Electronic Engineers (IEEE) at Case Western Reserve University in Cleveland, Ohio, USA, 21 May-23 May, 2013, USA. 2013

[108] Paul S, Khan KA, Kundu RK. Performance studies of mono-crystal silicon solar photovoltaic module with booster reflector under Bangladeshi climatic condition. In: Published in the Proceedings of IEEE, ENERGYTECH, USA. Participated and Presented in the "EnergyTech2013" Conference sponsored by the Institute of Electrical and Electronic Engineers (IEEE) at Case Western Reserve University in Cleveland, Ohio, USA, 21 May-23 May, 2013, USA. 2013

[109] Rahman AA, Khan KA. Feasibility studies on WEC (Wave Energy Converter) for use in coastal belt at Cox's Bazar of Bangladesh under the climate condition of the Bay of Bengal. International Journal of Engineering and Innovative Technology. 2013. 3660 East Bay Drive, Apartment no.116 Largo, Florida US,33771 (IMPACT FACTOR:1.895) (ISO 9001:2008 Certified)

[110] Khan KA, Latif A, Alam S, Sultana J, Ali H. A study on internal resistance of the Pathor Kuchi leaf (PKL) cell. Journal of Agriculture and Environment. 2014;**10**(1):24-28

[111] Ahasan MN, Quadir DA, Khan KA, Haque MS. Simulation of a thunderstorm event over Bangladesh using WRF-ARW model. Journal of Mechanical Engineering. Transaction of the Mechanical Engineering Division, The Institute of Engineers, Bangladesh. 2014;**44**(2)

[112] Uddin MK, Khan MKA, Sobhan MA, Ahmed F, Nabi MN. On the implications of dynamic wireless spectrum management canons issues in uncertainty use of cognitive radio. Bangladesh Electronics Society Journal (BESJ). 2015;**15**(1-2):17-24

[113] Uddin MK, Khan MKA, Ahmed F, Nabi MN. A concept of potential radio spectrum administration seeking easy access spectrum (EAS) paradigm figured on signal to interference noise ratio (SINR) and interference thresholds. Bangladesh Journal of Scientific and Industrial Research. 2016; **2015**. (in review)

[114] Uddin MK, Khan MKA, Sobhan MA, Ahmed F, Nabi MN. Dispensation of commons radio spectrum management framework issues in implementation: Challenges and opportunities. Journal of Electronic Engineering. 2015

[115] Uddin MK, Khan MKA, Sobhan MA, Ahmed F, Nabi MN. Dispensation of commons radio spectrum management using conceptual benefit and cost analysis framework issues in Bangladesh. Chittagong University Journal of Science. 2015

[116] Shamsuzzaman M, Sikder S, Siddiqua T, Rahman MS, Bhuiyan MMH, Khan KA, et al. Standardization of gamma radiation field for characterizing radiation detecting instrument at SSDL facilities in Bangladesh. Bangladesh Journal of

Physics (BJP). 2015;**18**(65-72). ISSN: 1816-1081, BPS

[117] Kabir MU, Sobhan MA, Khan MKA, Khan MAR. Broad network wide statistics of TCP indicator measurements to reassume the status of the wireless 3G network monitoring. University of Information Technology and Sciences (UITS) Journal. 2015;**4**(2) ISSN: 2226-3128

[118] Sruti RN, Islam MM, Rana MM, Bhuiyan MMH, Khan KA, Newaz MK, et al. Measurement of percentage depth of a linear accelerator for 6 MV and 10 MV Photon Energies. Nuclear Science and Applications, AEC, Dhaka, Bangladesh. 2015;**24**(1 & 2):29-32

[119] Uddin MK, Sobhan MMA, Ahmed F, Khan MKA, Nabi MN. A potential electrical and electronic debris management model and ecological impact and awareness issues in Bangladesh. National University Journal of Science. 2015;**2**(1). ISSN: 1994-7763

[120] Hasan MM, Khan DMKA, Rahman MN, Islam MZ. Sustainable electricity generation at the coastal areas and the Islands of Bangladesh Using Biomass Resource. City University Journal. 2015;**2**(1):09-13

[121] Kabir MU, Ahmed PDF, Sobhan DMA, Khan MKA. Dispensation of commons radio spectrum management framework issues in implementation: Challenges and opportunities. Bangladesh Electronic Society (BES). 2016;**16**(1-2). ISSN: 1816-1510

[122] Khan KA, Alam MS, Mamun MA, Saime MA, Kamal MM. Studies on electrochemistry for Pathor Kuchi leaf power system. Journal of Bangladesh Journal of Agriculture and Environment. 2016;**12**(1):37-42

[123] Akter T, Bhuiyan MH, Khan KA, Khan MH. Impact of photo electrode thickness and annealing temperature on natural dye sensitized solar cell. Elsevier. 2016. Ms. Ref. No.: SETA-D-16-00324R2

[124] Khan KA, Rasel SR, Ohiduzzaman M. Homemade PKL electricity generation for use in DC fan at remote areas. In: 1st International Conference on 'Energy Systems, Drives and Automations', ESDA2018. 2018. pp. 90-99

[125] Khan KA, Yesmin F. Solar water pump for vegetable field under the climatic condition in Bangladesh. International Journal of Advance Research and Innovative Ideas in Education. 2019;**5**(1):631-641

[126] Khan MKA. Performance of electricity generation from *Bryophyllum* leaf for practical utilization. Bulletin of the American Physical Society. 2017;**62**(1). Abstract published and Presented in the APS April Meeting, January 28-31, Session T1 (Page No.: 201), Washington, DC, USA

[127] Ruhane TA, Islam MT, Rahaman MS, Bhuiyan MMH, Islam JMM, Newaz MK, et al. Photo current enhancement of natural dye sensitized solar cell by optimizing dye extraction and its loading period. Optik: International Journal for Light and Electron Optics. 2017. Available online 6 September 2017. In Press, Accepted Manuscript-Note to users

[128] Khan KA, Rasel SR. Solar photovoltaic electricity for irrigation under Bangladeshi climate. International Journal of Advance Research and Innovative Ideas in Education. 2019;**5**(2):28-36

[129] Khan KA, Rasel SR. The present scenario of nanoparticles in the world. International Journal of Advance Research and Innovative Ideas in Education. 2019;**5**(2):462-471