Transformation of Water to Evaporation and Long Range Discharge System

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ABSTRACT – Evaporation innovations through nozzle sprinklers and long range discharge systems are created based on the occurrence of stagnant floods at identified locations. Stagnant floods are water in an area that does not recede for 10 days and at the same time can damage the activities of the population such as agriculture, fishing, and other activities, this will also increase the cost of repairing existing activities after the flood. This innovation will test 5 types of nozzles of various designs as well as various forms of spray into the air in the laboratory and from this study will determine which nozzle is most suitable to be installed during a stagnant flood in an area. In addition, this innovation is equipped with a long range discharge water system where if the flood water is too high then this system is used to move the flood water. Adjustable arc spray nozzle, field sprinkler, green garden, fountain nozzle, and fan or vapor blower have been tested where green garden spray type and fan or vapor blower will produce high evaporation which is between 9.5 percent to 18 percent but the water discharge from stagnant floods is low at 4.8 liters in 10 minutes. While the fountain spray nozzle also shows a high percentage of evaporation which is up to 15 percent and water discharge is also high is 409 liters in 10 minutes. However, the selection factor of the type of spray nozzle depends on the objective or requirements. The objective of the project is to determine the effectiveness of the sprinkler nozzle design and water discharge before being installed at the site.

KEYWORDS : Sprinkler nozzles, evaporation, water discharge, hydro-mechanical system, and environment

1.0 INTRODUCTION

Floods are one of the natural disasters where it will have a bad effect on humans, agriculture, aquaculture and others if stagnant water for a long time. In general, the problem of floods occurs due to several factors is based on natural factors or human activities. The issue of flood disaster is not a normal matter for countries that have often been affected by climate changes factors [1]. Among the natural factors such as continuous rain, sea tides and terrain conditions of an area (topography) while human activities are urbanization, river erosion, forest destruction, unplanned drainage system and maintenance. In general, stagnant floods occur due to water that does not recede over a period of time, even though the rains have stopped because the water cannot flow to lower areas due to tidal factors, topography as well as clogged areas and drainage. The flood become a problem when it interferes with the activity of human lives and livelihoods even threating her safety [2].

An innovative design by using the method of water to mist/ evaporation by nozzle sprinkler which converts the percentage of water to mist through evaporation in addition to being able to discharge water in flooded areas mist / vapour occurs during the evaporation process caused by the reaction of small liquid droplets as a result of being sprayed and dispersed in the air in contact with atmospheric air. In liquid spray applications, flow development inside the injector nozzle is crucial to the spray dynamics, specifically to the breakup of the initially continuous liquid jet [3]. Evaporation occurs from the surface of the water droplets; the total surface area of the water droplets greatly affects the amount of evaporation loss. Nozzle design determines the average size of sprayed droplets. Instant flash-evaporation is sought-after feature in mist cooling, thus smaller orifices mated with high pressure pumps are generally preferred [4]. Meteorological variables, such as wind speed (W) and direction, are the main factors that influence the water distribution pattern in sprinkler irrigation, playing an important role in wind drift and evaporation losses [5].

The innovation of this system is one of the methods to solve the problem of floodwater that has been stagnant for a long time and needs to be reduced immediately to prevent further damage such as property, agriculture, aquaculture and others. The operating method of this transformation innovation, where floodwater will be pumped using a suitable pump to send water from the stagnant flood area to a predetermined location by the method of water discharge and evaporation using a sprinkler nozzle through a pipeline sprayed into the air with proper planning. Water supply systems need to be designed in an efficient way, accounting for both construction costs and operational energy expenditures when pumping is required. Since water demand varies depending on the moment's necessities, especially when it comes to agricultural purposes, water supply systems should also be designed to adequately handle this [6]. It could possibly provide ambient air humidity upon evaporation due to the reaction of water droplets with atmospheric air during water at the pump is sprayed through a nozzle from a stagnant flood area.

In general, the objective for the innovation of water to mist/ vapour/ evaporation by nozzle sprinkler is one of the methods to solve the problem of stagnant flooding in an area that has been identified. Mala-Jetmarova provide an excellent summary of the state of the art in water distribution designs, providing a clear classification of the optimization methods according to the objectives of the optimization (e.g., single objective, multi objective, and others) or the calculation method (e.g., stochastic, heuristic, and others) [6]. The following are the objectives of the transformation method adopted: (i) to test the percentage effectiveness of the sprinkler nozzle design for the production of water to mist/ vapour and ensure that the nozzle selected to be installed in the system is appropriate; (ii) to identified as water discharge alternative for stagnant flood problems for a long term period; and (iii) to determine the application for green technology in controlling the negative effects on daily activities such as agriculture, aquaculture and others.

2.0 METHODOLOGY

To meet the objectives of this research and development, the scope of work that has been outlined includes the following: (i) to test the percentage of water loss in the air on the reaction of small liquid droplets with atmospheric air during the evaporation process occurs for 5 nozzle units; (ii) to test 5 units of different nozzle designs to get the percentage of evaporation that occurs; (iii) to possibly increase the water flow rate in the system for each specified time to see the effectiveness of evaporation and discharge of floodwater; (iv) time is taken every 10 minutes to measure the percentage effectiveness of evaporation; and (v) possible to implement apprentice scale on site testing will also be done as a start to introduce water to mist/ evaporation transformation by nozzle sprinkler for one of the solutions to the problem of stagnant flooding.

2.1 Laboratory Testing Setting

The design of the test concept for the transformation of water to mist/ evaporation by nozzle sprinkler is as shown below which includes a water pump, pipe and sprinkler nozzle. Applied water is lost partially by evaporation, particularly through drift out of the irrigated area; second, under windy conditions, the water distribution pattern of an isolated Sprinkler is distorted and narrowed [5]. The water pump must be appropriate as supported by the statement the way performance of the whole system can be improved by several factors such as adding more blades to the water wheel, a steeper angle and better piston shaft design for the water pump, and also proper water sealing of the whole system to prevent head loss and increase the overall performance [7].

The concept of data collection in the laboratory is as follows: (i) at the stage before the water is pumped, the meter reading will be taken first to record the initial reading; (ii) water will be pumped from the water source provided through the meter reading and sprayed out through the sprinkler nozzle through test channel 1 or test 2 where the contact of water sprayed with atmospheric air will occur evaporation process. Only a few percent of the water will evaporate and the rest will fall into liquid; (iii) water that falls will continue to flow to the storage tank to be collected for the measurement process; (iv) upon reaching a reading every 10 minutes the pump operates, the final water meter reading will be taken and also the water reading in the storage tank will be taken for the purpose of determining what percentage of water to mist/ evaporation occurs in systems with various sprinkler nozzle designs; and (v) in this test, data will be taken every 10 minutes the pump operates with different water discharge rate readings, data will be taken to determine the percentage of water to mist/ evaporation that occurs. Each sprinkler nozzle will be read 6 times before being changed to another sprinkler nozzle. The design concept test as shown in Figure 1 below.

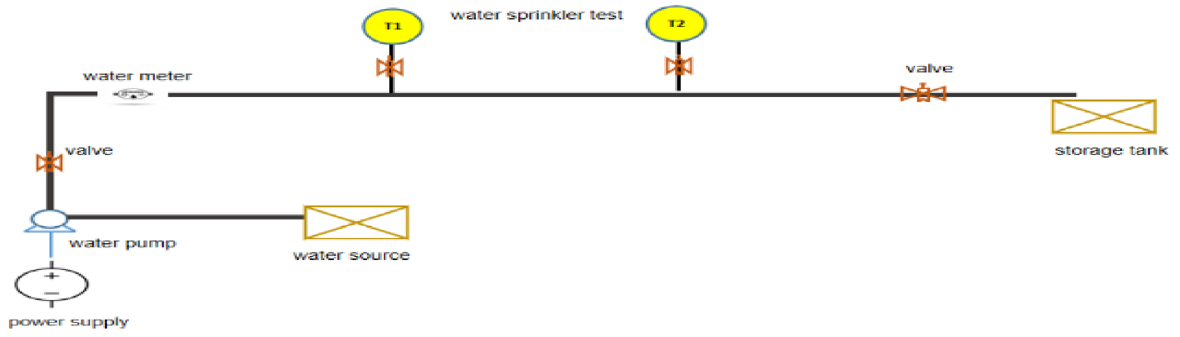

Figure 1. Design concept test

2.2 Type of Nozzle Tested

The design of the test concept for the transformation of water to mist / evaporation by nozzle sprinkler as shown in Table 1 which includes water pump, pipe and sprinkler nozzle. Applied water is lost partially by evaporation, particularly through drift out of the irrigated area; second, under windy conditions, the water distribution pattern of an isolated Sprinkler is distorted and narrowed [5]. The water pump must be appropriate as supported by the statement the way performance of the whole system can be improved by several factors such as adding more blades to the water wheel, a steeper angle and better piston shaft design for water pump, and also proper water sealing of the whole system to prevent head loss and increase the overall performance [7].

Table 1. Type of nozzle

No	Item	Spray type	Specification
1	Nozzle 1	adjustable arc	**Dimension**: height (18cm), Additional height (10.2cm), **Pressure**: 15 to 70 psi (1.0 to 4.8 bar), **Operation range**: 30 psi (2.1 bar), Allow the **nozzle** to be adjustable arc range: 0° - 360°, Flow rate: 0.04 m3/h (0.60l/m)
2	Nozzle 2	field sprinkler	**Dimension**: a) Radius: 15 to 35 feet (4.6 to 10.7 m) b) Length:11" (29cm) [Shrub: 7" (17.8cm) and 4" (10.2 cm)], **Pressure**: 25 to 55 psi (1.7 to 3.8 bar), **Nozzles deliver** even distribution over the entire radius, **Flow rate**: 0.54 to 4.6 gpm (2.0 to 17.4 l/min) and
3	Nozzle 3	green garden	**Dimension**: 4.5mm, 22 mm (Nozzle length) and 4mm, **Work pressure**: 1.5-3bar (each) , **The spray** head angle of rotation 180º and able to install into PVC/PPR/PE pipe, **Material**: Plastic And **Number used**: 6 amounts used during the experiment.
4	Nozzle 4	fountain nozzle	**Dimension**: 6mm (discharge diameter), 28 mm (length), 9.5mm (water enter diameter), **Pressure**: 30psi (2.0 bar), **Flow rate**: 27 (l /min) and **Material**: ABS / Brass
5	Nozzle 5	blower fan or vapour	**Dimension:** Size: 26" height [Fix: 175 Adjustable: 160-200], **Power:** 55 W, Provide 3 speed and the Spray effective distance [**5-8m**], **Follow rate** : 155(m^3/min) and **Material**: copper (motor), aluminium (blade), plastic (basin)

2.3 Site Testing

Site testing was also conducted in the flooded area of Kg. Parit Separap Batu Pahat Johor. This location was chosen because it was found that the stagnant flood water had reached 10 days without receding. The innovation transformation of water to mist/evaporation by nozzle sprinkler has been redesigned and installed as shown in Figures 2.

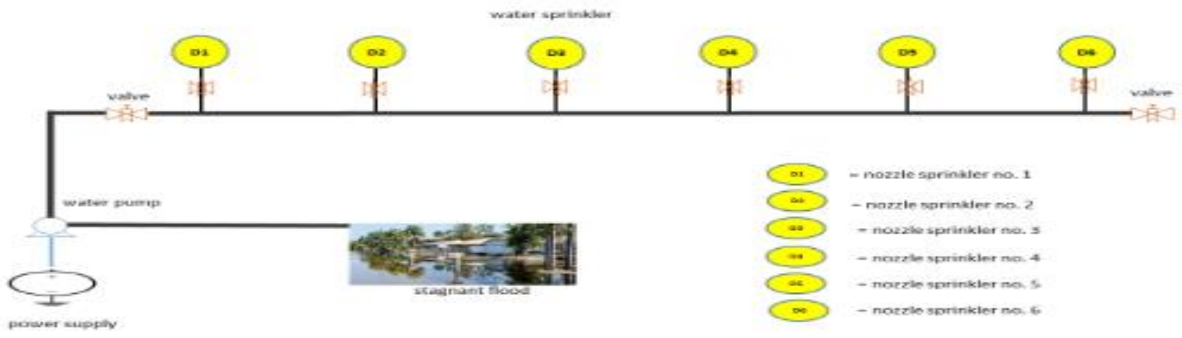

Figure 2. *On-site testing design*

2.4 Conceptual Design Consisting of Evaporation, Long Range Discharge System and Electrical Power Supply

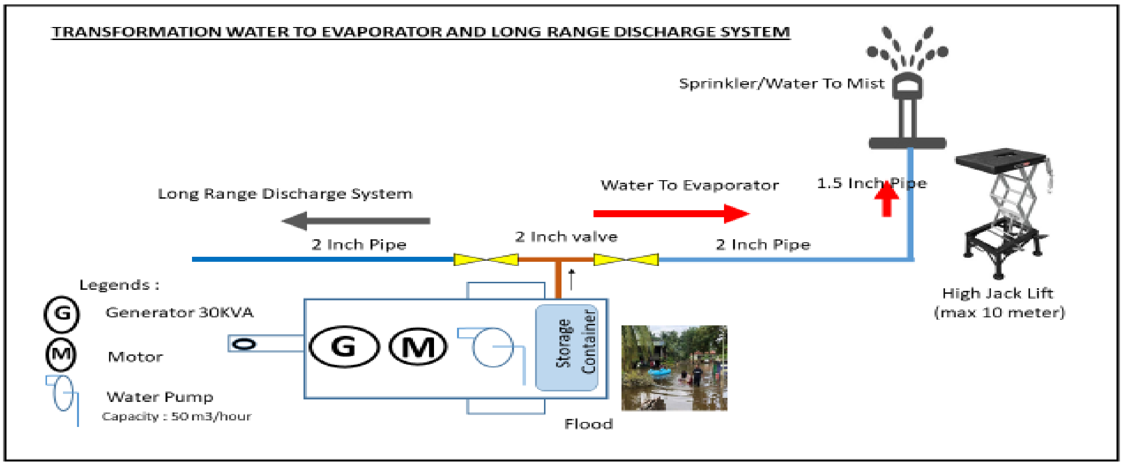

Figure 3. *Conceptual Design Consisting of Evaporation, Long Range Discharge System and Electrical Power Supply*

Figure 3 shows the design of this innovation is to carry out stagnant flood dispersal works through the development of an evaporator system complete with main equipment such as water pumps, power generator sets, water evaporator sprinklers, pipes, wheeled platforms, trucks and other related equipment.

The design concept of transformation of water to evaporation and long range discharge system has 3 functions:

i. Evaporator - used in the event of a stagnant flood
ii. Long Range Discharge System - used when the flood water starts to rise for the purpose of transferring flood water to other areas with the delivery distance depending on the terrain conditions in the flood zone.
iii. Generator set - used to supply electricity to equipment for the purpose of cleaning areas and houses after a flood.

3.0 RESULT AND DISCUSSION

3.1 Laboratory Testing Result

Laboratory Test Result of Data Collection Nozzle no.1 to Nozzle no.5 as shown in Table 2 to Table 6. Referring to table 7 above for an average of 6 readings for each 1 nozzle sprinkler shows a high percentage of evaporation readings are field sprinkler spray type nozzle, fountain nozzle and blower fan or vapour which is 9.6% but only fountain nozzle type that shows high water discharge that is in 303.5 liters in every 10 minutes while green garden spray type and fan or vapor blower show type a low quantity of water discharge which is between 4.6 to 17 liter in 10 minutes. The adjustable arc type spray nozzle shows the average reading of evaporation in a high state of 6.6% and water discharge is also high at 167.7 liters every 10 minutes. The design of the spray nozzle chosen depends on the objective or requirement of a project to be implemented. The main factors are air and water temperature, relative humidity, wind velocity, surface area, atmospheric pressure and salinity of the water [8]. The measurement results showed that better performance of the mist system at nozzle elevation is (2.25m) and water flow rate is (1.2L/min). The maximum temperature difference in space is (9.4˚C) and effectiveness of mist system is more than (62.5). Inlet water temperature variations has a slight effect on obtained results which was found to be (15.9%) for air temperature difference [9].

Table 2. Nozzle no.1 (Adjustable arc)

No	Time (minutes)	Water discharge (liter)	Balance of water (liter)	Water spray distance diameter (meters)	% Water to mist/ vapour/ evaporation
1	10	80.4	74.203	1.0 (d)	7.707
2	10	133.1	123.471	1.7 (d)	7.234
3	10	161.2	150.458	2.4 (d)	6.664
4	10	182.2	172.111	3.1 (d)	5.537
5	10	213.1	201.067	3.8 (d)	5.647
6	10	236.0	219.692	4.5(d)	6.910

Table 3. Nozzle no.2 (Field sprinkler)

No	Time (minutes)	Water discharge (liter)	Balance of water (liter)	Water spray distance (meters)	% Water to mist/ vapour/ evaporation
1	10	50.9	45.30	4.60	11.002
2	10	95.6	85.90	5.50	10.146
3	10	136.5	124.50	6.30	8.791
4	10	138.4	126.65	6.50	8.492
5	10	149.6	135.60	6.90	9.358
6	10	166.5	150.75	7.30	9.459

Table 4. Nozzle no.3 (Green garden)

No	Time (minutes)	Water discharge (liter)	Balance of water (liter)	Water spray distance diameter (meters)	% Water to mist/ vapour/ evaporation
1	10	46.0	42.441	0.4 (d)	7.737
2	10	53.4	49.327	0.5 (d)	7.625
3	10	102.0	92.243	1.0 (d)	9.566
4	10	118.0	111.294	1.2 (d)	5.684
5	10	125.2	117.137	1.3 (d)	6.440
6	10	156.0	141.912	1.6 (d)	9.031

Table 5. Nozzle no.4 (Fountain nozzle)

No	Time (minutes)	Water discharge (liter)	Balance of water (liter)	Water spray distance (meters)	% Water to mist/ vapour/ evaporation
1	10	156	154.372	5	1.044
2	10	237	228.979	6	3.384
3	10	291.9	258.811	7	11.336
4	10	352.3	305.129	8	13.389
5	10	375	324.129	9	13.566
6	10	409	348.986	10	14.673

Table 6. Nozzle no.5 (Blower fan or vapour)

No	Time (minutes)	Water discharge (liter)	Balance of water (liter)	Water spray distance (meters)	% Water to mist/ vapour/ evaporation
1	10	4.814	3.9	2.5	18.986
2	10	4.514	4.0	2.5	11.387
3	10	4.665	3.8	5.0	18.542
4	10	4.214	3.8	5.0	9.824
5	10	4.515	4.0	7.5	11.406
6	10	4.665	3.8	7.5	18.540

Table 7. Nozzle no.6 (Average data collection nozzle)

No	Nozzle	Water discharge (liter)	Time (minutes)	Water spray distance (meters)	% Water to mist/ evaporation
1	No. 1 (adjustable arc)	167.7	10	2.8	6.6
2	No. 2 (field sprinkler)	122.9	10	6.2	9.5
3	No. 3 (green garden)	102.0	10	1.6	7.7
4	No. 4 (fountain nozzle)	303.5	10	7.5	9.6

5	No.5 (blower fan or vapour)	4.6	10	5	14.8

There are some problems that influence the data collection. Some factors were identified during the data collection, tested in the laboratory environment, whereas in order to determine the percentage of evaporation readings for all nozzles, are: (i) surrounding weather factors; (ii) wind movement or speed factors; (iii) dry or humid atmospheric air factors; (iv) factors of equipment used; (v) human factors in terms of the use of measuring tools and time taking; and (vi) location factors so as to interfere with the process of evaporation between the water sprayed from the nozzle into the atmospheric air. Not with standing the need for field-collected evidence, many studies outline that, as fine water mist scatter within a turbulent airflow, strongly perturbed by natural wind (velocity, direction, gusts, buoyancy) [4].

3.2 Site Testing Result

The test and operation were generated using a water pump unit with 7 horsepower petrol fuel with a capacity of 33 m³ per hour and a total head of 60 meters maximum and the operating capacity of the test water pump is in the range of 30% of the actual power as Figure 4 and 5. The observations and monitoring carried out at the site showed the significance of this method with the evidence of the decrease in water level in the area of Parit Lintang no 4 by 20 m³ taking into account the area of the stagnant flood of 2,000 m² and system operation for 2 hours. Referring to the study conducted in the laboratory by taking into account the various types of sprinkler nozzles tested, it can be concluded that the deformation of this system occurs water to mist in the range of 8.62 % and is suitable for stagnant flood areas for water discharge and evaporation process.

Figure 4. Process water to mist / evaporation by nozzle sprinkler

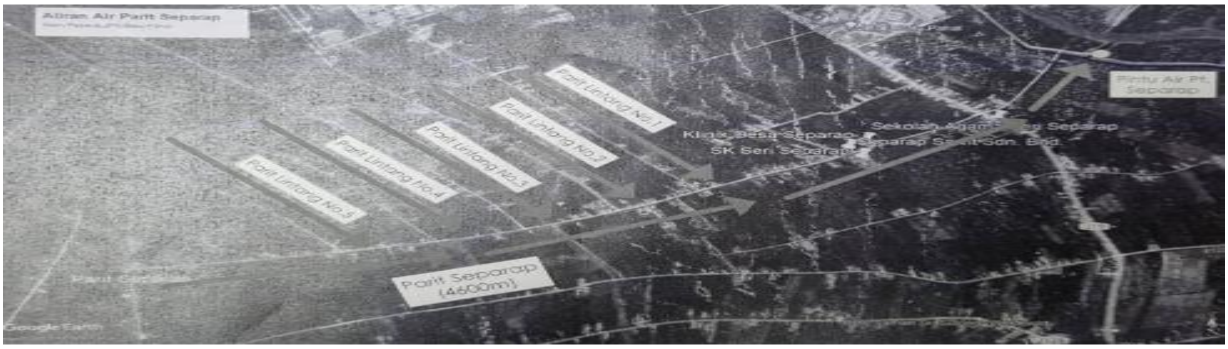

Figure 5. Location of stagnant flood incident in Parit Lintang no. 4

In order to ensure the efficiency of the water discharge and evaporation process occurs in the system then this innovation will be improved its design by taking into account the following information: (i) Increases the power and capacity of the water pump; (ii) The additional height of spray nozzle pipe from 3m to 15m for evaporation of water spray coming out of the nozzle into the more open-air; (iii) increase the length of the flexible type pipe starting from the water pump intake up to the nozzle pipe within a minimum of 500 meters; (iv) Replacing the generator water pump with battery solar power to ensure the safe environment and (v) Design the system is in the form of a vehicle and ready to wait and can be installed and dismantled for locations that need.

3.3 Spray Nozzle Type

Referring Table 2 to Table 6 show that the type of spray nozzle plays a role in determining the percentage of evaporation in the system where a small nozzle eye will spray more fine water droplets and a higher percentage of evaporation. Table 7 shows the average occurrence of water to mist / evaporate for nozzle no. 3 and no. 5 green garden spray and blower fan or vapour are 7.7% and 9.6% but the flow rate is very low where the water discharge process is also low but the percentage of evaporation is high. In this test the green garden spray uses 6 nozzles so for 1 nozzle is at a water flow rate of 17 liters in 10 minutes. The engineering design factors of sprinkler affect sprinkler system performance [10].

3.4 Spray Distance

Referring to Table 5 the spray form is a type of fountain nozzle that shows a long spray distance during operation until this study reaches 10 meters. Long spray distances can also increase the percentage of the evaporation process, that is, the longer the spray nozzle water is in contact with atmospheric air, the more evaporation will occur. The water discharge is also high at 409 liter in 10 minutes as in Table 5 and the average at 303.5 liter in 10 minutes as in table 7, this is due to its large nozzle hole design and is suitable for water discharge in stagnant flood conditions to help to reduce water. As to determine the applicability of the low-pressure rotating sprinkler, an experiment was conducted to evaluate the effects of working pressure and nozzle size on sprinkler rotation speed, application rate, droplet size, droplet velocity, droplet trajectory angle, and kinetic energy distribution [11].

3.5 Atmospheric Air

When it rains and floods then of course the surrounding air becomes moist and this will also reduce the percentage of evaporation of spray water from the nozzle when in contact with atmospheric air, while hot dry atmospheric air will increase the percentage of evaporation. This is a natural phenomenon that occurs in atmospheric air whether moist wet or hot dry. Evaporation is the transfer of water from liquid to gaseous state and its diffusion into the atmosphere [8].

4.0 CONCLUSION

The “Transformation of Water to Evaporation and Long Range Discharge System” which is a system that able to handle occurrence of stagnant floods at identified locations in Malaysia. Based on functions of this innovation system, it could help to reduce and prevent further damage such as property, agriculture, aquaculture and others. Thus, this study shows that the effectiveness of this innovation system influenced by the type of nozzle applied. This innovation system has been proved to be an alternative way to improvise the efficiency of problem solving in stagnant floods incident that often hit the whole country especially in the monsoon season.

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REFERENCES

[1] Nurashikin Sungip. F, Khairul Amri Kamarudin. M, Hafiz Md Saad. M, Abd Wahab. N, Puad Mat Som. A, Umar. R, Ing Hoe. L, Hakparn. S, Lertbunchardwong. K, Potikengrith. T, and Harith. H, "The Impact of Monsoon Flood Phenomenon on Tourism Sector in Kelantan, Malaysia: A Review," *International Journal of Engineering & Technology*, vol. 7, no. 4.34, pp. 37, 2018.

[2] Tambunan. M. P, "The pattern of spatial flood disaster region in DKI Jakarta," *IOP Conference Series: Earth and Environmental Science*, vol. 56, pp. 1, 2017.

[3] Agarwal. A and Trujillo. M. F, "The effect of nozzle internal flow on spray atomization," *International Journal of Engine Research*, vol. 21, no. 1, pp. 55–72, 2020.

[4] Ulpiani. G, "Water mist spray for outdoor cooling: A systematic review of technologies, methods and impacts," *Applied Energy*, 2019.

[5] Sheikhesmaeili. O, Montero. J and Laserna. S, "Analysis of water application with semi-portable big size sprinkler irrigation systems in semi-arid areas," *Agricultural Water Management,* pp. 275–284, 2016.

[6] Martin-candilejo. A, Santill. D, Iglesias. A, and Garrote. L, "Optimization of the Design of Water Distribution." *Article*, 2020, vol. *2*, pp. 2–20.

[7] Lee. M. D, Chan. J. Y, Ling. J and Lee. P. S, "Design and development of zero electricity water pump for rural development," *Universal Journal of Mechanical Engineering*, vol. 7, no. 6, pp. 441–449, 2019.

[8] Özgür E and Koçak. K. 2015, "The effects of the atmospheric pressure on evaporation," *Acta Geobalcanica*, vol. 1, no. 1, pp. 17–24, 2015.

[9] Mahmoud. M. S, "Experimental Study to Evaluate Mist System Performance," *International Journal of Innovative Research in Advanced Engineering (IJIRAE)*, vol. *2*, no. 9, pp. 41–48, 2014.

[10] Mohamed Kheir. E, Hegazi. M, elbagoury. K and Mokhtar Desoky. W, "Effect of Nozzles design on the performance of Impact Sprinklers in sprinkler irrigation system," *Arab Universities Journal of Agricultural Sciences*, 2020.

[11] Chen. R, Li. H, Wang. J, and Guo. X, "Effects of pressure and nozzle size on the spray characteristics of low-pressure rotating sprinklers," vol. 12, no.10, pp. 1–21, 2020.