BINDURA UNIVERSITY OF SCIENCE EDUCATION

DESIGN AND DEVELOPMENT OF A SELF-CLEANING FILTER POWERED BY SOLAR FOR IRRIGATION SYSTEM

BY

SIWOMBE EDGAR TENDAI

B1850873

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE HONOURS DEGREE IN AGRICULTURAL ENGINEERING OF BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ENGINEERING

SUPERVISOR: ENGINEER O. GWATIDZO

JUNE 2023

DECLARATION

I, Siwombe Edgar T (B1850873), thus declare that this paper is the result of my own studies and research, except to the extent mentioned in the acknowledgments and references. This project has not been submitted in part or in full to any other university. As a result, no part of this research, in any form, electronic or photocopy, may be duplicated for any purpose other than academic without permission from the undersigned. I further disclose that this study was approved by Bindura University of Science Education.

Signatures

Student…………………………………………………….

Supervisor ………………………………………………….

Date……. /………/…………

DEDICATION

This project is dedicated to the Siwombe family, particularly my parents, Mr. and Mrs. Siwombe, who pushed me to think optimistically and believe in myself. My brothers, sisters, and girlfriend, who were my pillars of strength and drive in all facets of my life.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank the Almighty God for providing me with assistance, strength, and good health in attaining all of my academic goals. I also thank him for his mercy and grace shown to me during my time at Bindura University of Science Education and throughout my life. I would like to convey my heartfelt appreciation and gratitude to my academic supervisor, Engineer O. Gwatidzo, for their consistent follow-up, excellent direction, support, and valuable critique during my study time, which has kept me on track. I wish I could name everyone who helped me finish my studies in some way, but there are far too many to name. In general, I would want to thank everyone.

ABSTRACT

To address impellor abrasion and nozzle clogging, a self-cleaning filtration mechanism for irrigation water was designed from locally accessible materials. Back flushing, scrubbing, and scraping were used to remove filter cake. The device was designed using AutoCAD 2007 and SolidWorks 2020, as well as the machine design principle. Fabrication and testing were carried out at the Bindura University of Science Education workshop. The majority of the components were manufactured with iron for strength and HDPE for corrosion resistance. Filter element speed and discharge were varied against filtration duration, and water amount variation was evaluated against filtration quality in four sets of constant speed and discharge. According to the findings of the performance tests, the machine has an optimal efficiency of 80 percent. %, and an output of at least 60 m3/h with a TSS of no more than 35 ml/l. The suction device can effectively filter water for irrigation and is useful in other water treatment operations. The machine cost $286.00.

Table of content

List of figures

List of Tables

List of abbreviations and acronyms

MIS: Micro Irrigation Systems

FAO: Food and Agriculture Organization

EPA: Environmental Protection Agency

SCADA: Supervisory Control and Data Acquisition

ASABE: American Society of Agricultural and Biological Engineers

TSS: Total Suspended Solids

PLC: Programmable Logic Controller

BUSE: Bindura University of Science Education

HDPE: High Density Polyethylene

PE: Polyethylene

PM: Profit Margin

ISO: International Organization for Standardization

VAT: Value Added Tax

PH: potential hydrogen

TDS: Total Dissolved solids

Notations and symbols

% - percentage

P - Pressure

D - Diameter

r - Radius

τ - Permissible stress

m - Mass

h - Height

V - Volume

Kappa - kilo Pascal

^0C - degree Celsius

m - Metre

m^2 - square metre

m^3 - cubic metre

mm - millimetre

π - Pie or 22/7

ppm - parts per million

μ - micron

rpm - revolutions per minute

l - Litre

min - minute

CHAPTER 1

1.0 INTRODUCTION

This introductory chapter provides a summary of the design project that will be done. The sections of this chapter will highlight the background, goal of the project, justification for doing this project, the primary and particular objectives, constraints and delimitations of this project, and the main scope of the project.

1.1 Background

The world's ever-increasing population has put pressure on agriculture to enhance food production not only for food security but also as a tool for improving incomes. As a result, agriculture has the enormous problem of boosting food production to fulfil the demands of a growing population predicted to reach 9 - 10 billion by 2050, while simultaneously reducing agriculture's global environmental footprint (FAO, 2002). Global food supply has expanded fast during the last half-century, but an estimated 790 million people are still hungry (Postel, 2001). Inadequate irrigation facilities in arid and semi-arid areas were identified as the two key obstacles in crop production (Dhaka, 2006). Irrigated agriculture is the world's largest water consumer. Agriculture irrigation is used in dry and semiarid zones.Because of lower rainfall and unpredictable patterns, micro irrigation systems (MIS) are gaining popularity around the world, particularly in locations with limited and expensive water supplies, because they allow limited resources to be more completely utilized. Micro irrigated lands expanded gradually from 1.1 million ha in 1986 to around 3.0 million ha in 2000 (FAO, 2000). Micro irrigation is already used in over 70 countries, covering an area of more than 6 million ha (SNE, 2006). As a result, irrigation development is the most essential interaction between water and land resources, and it should be prioritized as a means of improving food and raw material output.

Because roughly 70% of Zimbabwe's community lands are located in Natural Regions IV and V, which are characterized by inconsistent and unpredictable low rainfall (FAO, 2000), the government of Zimbabwe considered the establishment of irrigation schemes as a famine relief solution. As a result, rain-fed agriculture is unable to support optimum crop production under these climatic conditions (Rukuni, 2006). Climate change is having an impact all over the world. In light of these changes, water as a resource should be continuously managed and sustained to attain maximum productivity. To make irrigated agriculture more sustainable, it is widely agreed that water demand should be lowered through increases in water application uniformity. This is because water is a scarce, finite, and valuable resource, as well as one of the most important. Because of water constraint and recent technological advances, most community farmers in natural regions IV and V have chosen pressurized irrigation systems. However, because most large pressurized irrigation systems collect water from open sources such as rivers and dams, there are water quality issues. Impellers on centrifugal pumps are constantly prone to wear owing to internal abrasion. As a result, irrigation pipelines and emitters might become clogged. Sand, silt, debris, organic matter, twigs, stones, caddis-fly larvae, pond snails, and other suspended solids that are conveyed in irrigation water tend to rub against impellors and collect on irrigation pipelines and emitters.

This is due to both natural pollution of water sources caused by river loads from its catchment region and pollution caused by humans. Sediment transport into water sources and bodies reduces water quantity and quality, raising the expense of water purification while decreasing accessible water for other applications. Human-influenced activities also play a significant effect in the contamination of irrigation water sources such as rivers (Lawson, 2011). Such activities include the disposal of plastics and other non-biodegradable materials. Water contamination is primarily caused by effluent from companies and households. The suspended solids are directly related to sedimentation (Chapman, 1996). When these suspended particles settle at the bottom of a body of water.

Excessive fertilizer use encourages the growth of algae and water weed, which reduce water levels while impeding pump suction. Effluents are employed in agriculture as a feasible alternative to freshwater in locations where water is scarce or there is intense competition for its usage. Although micro irrigation is the most advantageous irrigation system for applying effluents, especially in terms of public health and the environment, the use of effluents can increase emitter clogging (Bucks et al., 1979), which affects water distribution and, as a result, crop yields (Tajrishy et al., 1994). As a result, filtration is an important operation that can prevent emitters from becoming clogged (Oron et al., 1979), while it cannot totally prevent it (Tajrishy and Hills, 1994). The holes of the filter medium are smaller than the size of the particles to be separated. When feed is passed through the filter medium, the fluid flows through the filter medium due to a pressure differential across the filter. A sucking force is acting on a fluid column. As a result, solids are trapped on the surface of the filter medium, and after a certain period of time, the resistance offered by the filter cake is great enough to halt filtration (Sambhamurthy, 2005). Reduced filtration results in a reduced volume of water pumped. Irrigation pumps overwork as a result of the additional energy required to transport water from the suction to the delivery point caused by the higher load of solids in the water. Pumping expenses will rise in the future to compensate for leaks caused by pipe bursts caused by internal wear. Because emitter clogging is difficult to detect and expensive to clean or replace, it is the most significant maintenance issue confronting pressured irrigation systems, preferring drip. This has a greater impact on the performance of irrigation systems like as centre pivot and overhead sprinkler systems. Sprinkler nozzle obstruction affects water distribution consistency, resulting in significant crop loss owing to insufficient water availability. There are critical growth periods that require appropriate water (Rao et al., 2010). The critical growth period is the stage(s) of crop growth at which moisture stress has the greatest effect on yield quality and quantity. These stages include the germination period, flowering, and fruit development; any stress during these stages will result in an irreversible reduction in output.

According to FAO (2012), in an agricultural setting, water extraction is continuous, therefore there is little time to clean the suction screens. Crops are irrigated during the day and evening, depending on the irrigation cycle. Anytime the screen suction becomes blocked as suspended particles are caught by the filter element, the filtration rate reduces and it must be cleaned to restore operational conditions, which creates many difficulties if detected late. As a result, pumping must be halted to allow for screen cleaning. As a result, suction screen cleaning can be done continuously without interrupting pumping. This topic focuses on the design and manufacture of a suction self-cleaning mechanism for a sediment suction device.

1.2 Problem Statement

Due to impeller abrasion and nozzle blockage, small and medium-sized farmers in Zimbabwe are experiencing considerable irrigation downtime. Inefficiencies in suction cleaning devices are to blame. Pumping must cease to allow for filter element cleaning, causing irrigation to be disrupted. Because modern designs use advanced technology, local farmers cannot afford them. As a result, a technology that tackles these difficulties is required.

1.3 Project aim

To create a sediment self-cleaning filter for irrigation water capable of handling medium-60 m3/h with total suspended solids (TSS) of no more than 35 ml/l.

Objectives

1. To determine the water discharge of the filter per hour.

2. Determine the infiltration time at different speed and flow rate of water.

3. To evaluate the filter's effectiveness and efficiency the flashed impurities per hour.

1.4 Justification

This research aims to fill a void created by previous conventional design. Self-cleaning filters and strainers are the finest solution for conventional filters and strainers. They do not have the same problem as the traditional. The self-cleaning pump suction screen removes big garbage and debris from water sources, saving time and money in energy, pumping efficiency, and maintenance expenses. This increases the capacity and effectiveness of filtration, resulting in more effective irrigation by minimizing sediment collection on the screen element, impeller wear, and nozzle clogging. This allows for continuous watering without having to stop pumping for suction clean-up, resulting in greater irrigation time and less labour. Pump and pipe operational life is also increased.

1.5 Limitations

The fabrication method is confined to the workshop technology and equipment accessible at Bindura University Science Education (BUSE).

Delimitations

The research focuses solely on sediment water treatment for irrigation.

1.6 Assumptions

Materials necessary for fabrication are presumed to be locally available.

1.7 Conclusion

Overall, the major goal of this design and development project is to prevent suction filter cake building on the filter element, which could lead to early blockage. This will also degrade impellers and restrict irrigation lines and emitters. Suction self-cleaning is critical in the purification of water. Because most self-cleaning filters only require a semi-annual check and may be incorporated into SCADA or other monitoring systems, little to no time is lost cleaning the screens, which improves continuous watering and reduces labour.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

This chapter will analyse the literature on the challenges associated with the available suction manual basket cleaning methods, automobile -self-cleaning suction, and the integration of these designs in the production of the required self-cleaning filter for farmers in Zimbabwe.

2.1 Brief history of suction filtration and straining

The removal of any size particle from a stream of water is known as filtration. It is a procedure that involves passing water through material in order to remove particle and other contaminants, such as floc, from the water being treated (EPA, 1995). Suspended solids are made up of both inorganic and organic constituents. A portion of the organic fractions are bacterial, which could be harmful to human health if the water is not properly treated (Hoko, 2008). Suspended particles (fine silts and clays), biological debris (bacteria, plankton, spores, cysts, or other stuff), and floc are among the contaminants. In 1996, European technology mastered the weaving of tiny stainless-steel wires into a screen with 10 micron tolerance holes (EPA, 1995). This paved the path for automatic screen filters that self-clean.

Table 2.1 shows how the filtration spectrum divides solid particle sizes into five segments ranging from sub molecular ions to macro particles.

Table 2. 1 Filtration spectrum (Marcus, 2005)

Range	**Size (micron)**	**Examples**
Ionic	<0.001	Sodium, calcium, iron
Molecular	0.001 – 0.1	Sugar, virus, gelatine

Macro-molecular	0.1 – 1.0	Tobacco smoke, bacteria
Micro-particular	1.0 – 10	Red blood cells, flour
Macro-particular	10 – 3500	Pollen, beach sand

A water quality analysis is therefore required to determine the quantities of agents of impeller abrasion and clogging in order to devise effective control measures. Bucks and Nakayama (1991) discovered relationships between water characteristics and clogging hazard levels (Table 2.2).

Table 2. 2 Relationship between water characteristics and the hazard level of clogging (Bucks and Nakayama, 1991

		Hazard level	
Low	**Problem**	**Moderate**	**High**
	Physical		
<50	Total suspended solids (TSS) (ppm)	50 – 100	>100
	Chemical		
<7	pH	7 – 8	>8
<500	Total dissolved solids (TDS) (ppm)	500 – 2000	>2000
<100	Bicarbonate (ppm)	100	>100
<0.1	Manganese (ppm)	0.1 – 1.5	>1.5
<0.2	Hydrogen-sulphide (ppm)	0.2 – 2.0	>2.0

	Biological		
<10 000	Bacterial population (count per millimetre)	10 000 – 50 000	>50 000

The removal of bigger solid particles from a fluid is referred to as straining. According to EPA (1995), a common misperception is that particles are removed mostly by physical straining during the filtration process. Straining is the process of removing particles from a liquid (usually water) by passing the liquid through a filter or fabric sieve with holes smaller than the particles to be removed. While straining processes do play a role in the overall removal process, particularly in the removal of large particles, it is crucial to note that the majority of particles removed during filtration are much smaller than the pore spaces in the media (Parksanfilters, 2010). This is especially true at the start of the filtration cycle, when the pore spaces are clear (that is, not congested by particulates removed by filtration). To achieve high removal efficiency, a multitude of interconnected removal processes inside the filter medium itself are used. These removal techniques include the following procedures:

2.2 Filtration Methods

2.2.1 Kinetic Filtration

The cyclonic type separator, according to Benham and Payero (2001), best exhibits kinetic filtration or separation. This process moves a proportion of the numerous macro-particles present in the raw fluid stream by utilizing the dynamic physical forces of angular acceleration, velocity, and specific gravity differentials. The solid particles must have a specific gravity that is significantly greater than the fluid's.

2.2.2 Surface Filtration

It is a sieving method that employs a medium, such as a screen element, to provide a two-dimensional physical barrier to particles that are too big to pass through its holes or openings. It is a screening action that prevents particles from passing through pores or holes in the media (Patel et al., 2010). Surface filtering is accomplished through the mechanisms of straining and impingement; for this purpose, plates with holes or woven sieves are used. Matteson (1987) uses cellulose membrane filters as an example.

2.2.3 Contact Filtration

Granular media filters are examples of contact filtration. Impingement and adhesion on the surface of media granules, as well as entrapment between media granules, keep suspended particulates in the fluid stream within the medium. A long-standing example of a contact filter is the sand filter (Marcus, 2005).

2.3 Strainer Cleaning methods

Strainers can be cleaned by many different methods. Some simply require a filtering element to be removed, discarded and replaced with a new element.

2.3.1 Manual cleaning

The manual cleaning method requires the screen element to be removed and cleaned by hand. This can be accomplished by running water, high-pressure spraying, brushing or other physical means.

2.3.2.0 Back flushing

It's necessary to turn off the strainer. The fluid is subsequently forced backward through the filter, removing particles from the media or element and expelling them from the strainer body (Marcus, 2005). This approach cleans sand filters. The velocities in the filter system are equivalent after the cleaned open area of the screen (the sum of open holes) reaches the same area (for example, square millimetres) as the inlet and outlet flanges (Advantech, 2006). This also means that the energies are equivalent, that there is no energy differential across the screen, and that no additional screen cleaning is possible. The open regions of wave-wire screens are 5 - 10 times the cross-sectional area of the inlet and outlet flanges, and the differential pressure across the screen is 5 - 10 times the cross-sectional area of the inlet and outlet flanges.

2.3.2.1 Nozzle design

According to Gordon (2018), the basic function of a nozzle is to control flow rate and convert spray liquid into droplets of proper size for depositing on the intended target (through atomization). Flow rate is affected by orifice size, operating pressure at the nozzle, and, to a lesser extent, the specific gravity and viscosity of the spray solution. Spray quality is influenced by nozzle design, operating pressure, spray pattern angle, and the incorporation of air into the droplet. High jet velocity is essential for effective debris removal. The flow rate of ISO nozzles is measured in US gallons. At 300 kpa, a 01 orifice generates 0.39 l/min.

Table 2. 3 ISO nozzle flow rates at 300 kpa (Gordon, 2018)

01	015	02	025	03	04
0.39 l/min	0.68 l/min	0.79 l/min	0.99 l/min	1.18 l/min	1.58 l/min

2.3.3 Forced back flushing

According to Dennis (1987), forced back flushing is also known as suction scanning, which is the act of creating a suction force on a small section of the screen element. This suction is caused by the differential pressure between the system's positive working pressure and ambient pressure. The little piece of the screen area cleaned by this suction action and the subsequent reverse flow through the screen element in this limited area is transported across the screen surface to progressively clean the entire screen. A suction scanner is utilized to confine the cleaning of the screen to a narrow constrained area (Marcus, 2005). The suction scanner is nothing more than a hollow tube with one end very close to the screen surface and the other end far away. The difference in pressure between the inside of the strainer body (the fluid working pressure) and air pressure (zero-gauge pressure) produces enormous suction in a limited area near the screen surface. The filter cake (caught debris) is swiftly vacuumed off the screen and ejected into space. The suction scanner is then moved across the whole surface of the screen in under a minute to remove any particles. Meanwhile, the filtration process proceeds uninterrupted.

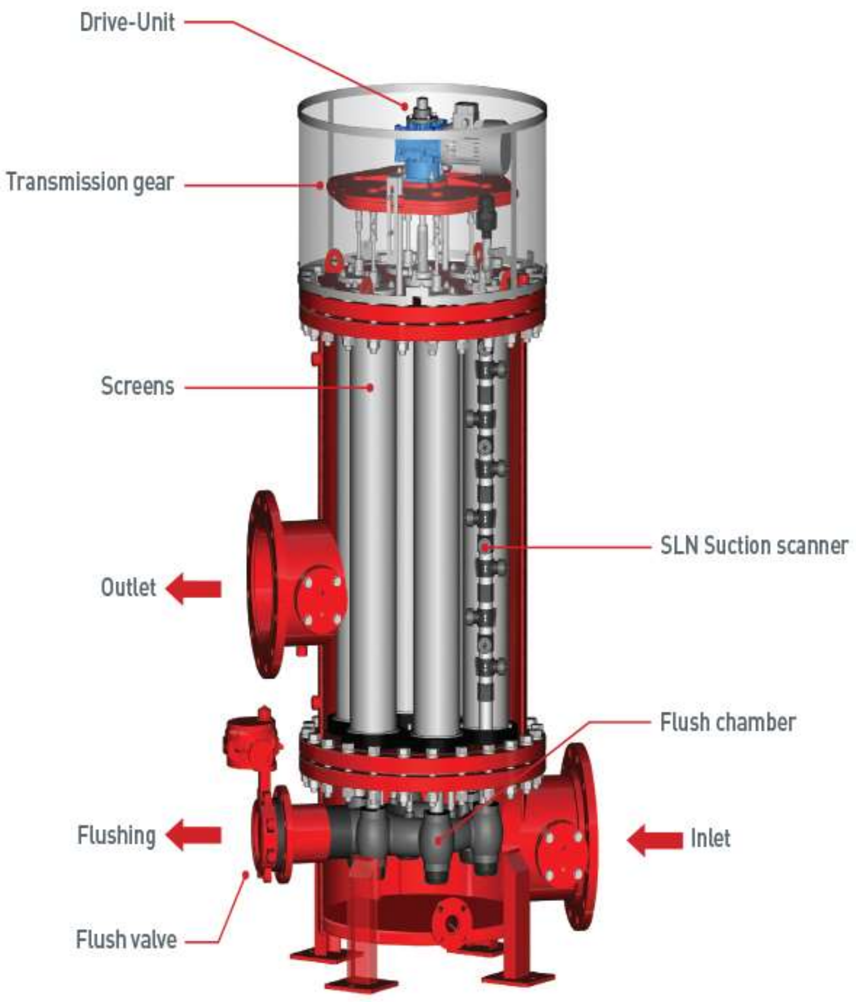


Figure 2.1 shows an automatic suction strainer utilizing suction scanning method of screen cleaning (https://www.amiad.com

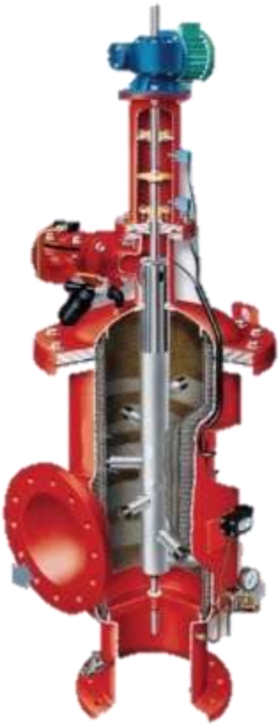


Figure 2.2 shows a cutaway of a Nankeen strainer utilizing suction scanning method of screen cleaning (Marcus, 2005).

Filthy water enters the strainer housing through the inlet flange at the bottom. The water flows into the 316 L stainless steel cylindrical screen element, through the screen, and out the side outlet flange. Benham (2001) describes how macro particles or trash are collected on the inside surface of the screen and form a filter cake. As the filter cake builds up, the fluid pressure across the screen drops. A pressure differential switch compares the pressure within and outside of the screen element on a continuous basis. When a predetermined differential pressure is attained, the differential pressure switch alerts the programmable logic controller (PLC) that a cleaning cycle is about to begin.

The hydraulic diaphragm exhaust valve is first opened to atmospheric pressure by the PLC. This valve is linked to the hollow 316 stainless steel suction scanner, which features nozzles with extremely close to the screen surface holes in the ends. According to Joseph (2006), the differential pressure at each nozzle hole induced by the difference in working gauge pressure

(241.32 - 1034.22 kPa) and atmospheric gauge pressure (0 kPa) results in a low-pressure area at each nozzle. Because of the low pressure, water flows backward through the screen in this little area, sucking filter cake off the screen and sucking it into the suction scanner before exiting via the exhaust valve to the waste. During this process, the PLC activates the electric drive unit, which slowly turns the suction scanner at a pace that does not disturb the filter cake except where it is sucked into the scanner at the nozzles. A threaded shaft transports the suction scanner linearly between two limit switches. This causes each suction scanner nozzle to spiral, allowing the scanner to suck the entire screen surface clean in 12 - 40 seconds, depending on the filter model (Marcus, 2005). When the upper limit switch is activated, indicating that every square millimetre of the screen has been covered by nozzles, the PLC checks the pressure differential switch to ensure that the pressure drop across the screen is less than a certain threshold. If this is the case, the PLC closes the exhaust valve and the drive unit reverses to move the scanner down to its starting position at the lower limit switch. The drive unit comes to a stop, and the system waits for pressure drop across the screen. If the pressure differential across the screen exceeds 6.89 kPa, the cleaning operation will be repeated. This will continue indefinitely or until the PLC software detects a malfunction and executes a present function, such as turning on a warning light, stopping a pump, or opening a by-pass.

Advantage and disadvantage of suction scanning

Cleaning is done only when necessary, resulting in less water and energy loss. Suction scanning eliminates the requirement for the filter to be isolated during the self-cleaning procedure. The concentrated cleaning and reduced exhaust requirements allow for continuous process flow. Suction scanning, on the other hand, cannot withstand clogging and fouling when confronted with huge solids and high solids concentrations. Backwash strainers cannot remove large solids and will clog, necessitating manual solid removal and filtration cleaning (Marcus, 2005).

2.3.4 Mechanical cleaning

Many strainers employ a mechanism to mechanically clean the screen element. Brushes, wipers, and scrapers are examples of such tools. This type of cleaning is typically utilized on screens with filtering degrees more than 200 microns (Patel et al., 2010). Figure 2.3 depicts a cross section of a brush cleaning mechanism (https://www.amiad.com).

Figure 2. 0-1 Brush cleaning strainer (Yuwei Filtration Equipment co Ltd USA)

2.3.5 Direct flushing

It entails exposing the strainer body to the atmosphere throughout the filtration operation. This wipes trash off the screen element without altering the flow direction. This method causes the water to flow at high velocity at a tangent to the screen, removing filter cake from the filter element (Patel et al., 2010). This sort of cleaning is only effective under certain conditions.

Conclusion

The research included in this chapter demonstrates the extent to which irrigation specialists throughout the world have dealt with impeller abrasion and blockage caused by insufficient suction filtration or straining. Filtration is a critical component of an irrigation system that gets its water from a non-potable source. Filtration is essential for protecting all system components, from the pump to the emission devices. As a result, an auto-controlled mechanism is required to push away filter cake build-up on the filter element.

CHAPTER 3

Design Solution, Analysis and Synthesis

3.0 Introduction

This section depicts the real design of solutions and their attributes. In the same way, the design's shortcomings are highlighted. The brainstorming process was completed and solutions to the problem at hand were drawn. Furthermore, in AutoCAD 2007 and Solid-works 2020, a mixture of both 2-D and 3-D views was created.

The solutions were evaluated after the designs had been brainstormed. The effectiveness of debris clearance.

- Feasibility.
- Manufacturing expenses.
- Convenience.
- Power source.
- Ease of maintenance.

The above variables that were to be used in the ranking and decision of the solution were to be done with a percentage range of 0% to 100% each factor. The design with the highest overall percentage would be considered the best to be implemented as a solution.

3.1 Design components

The suction self-cleaning filter is made up of the following major components:

- Brush.
- Scraping blade.
- Back flush nozzles.
- Debris collection hopper.
- Frame

3.2 Possible solution 1 (brush)

The first possible solution is shown in Figure 3.1

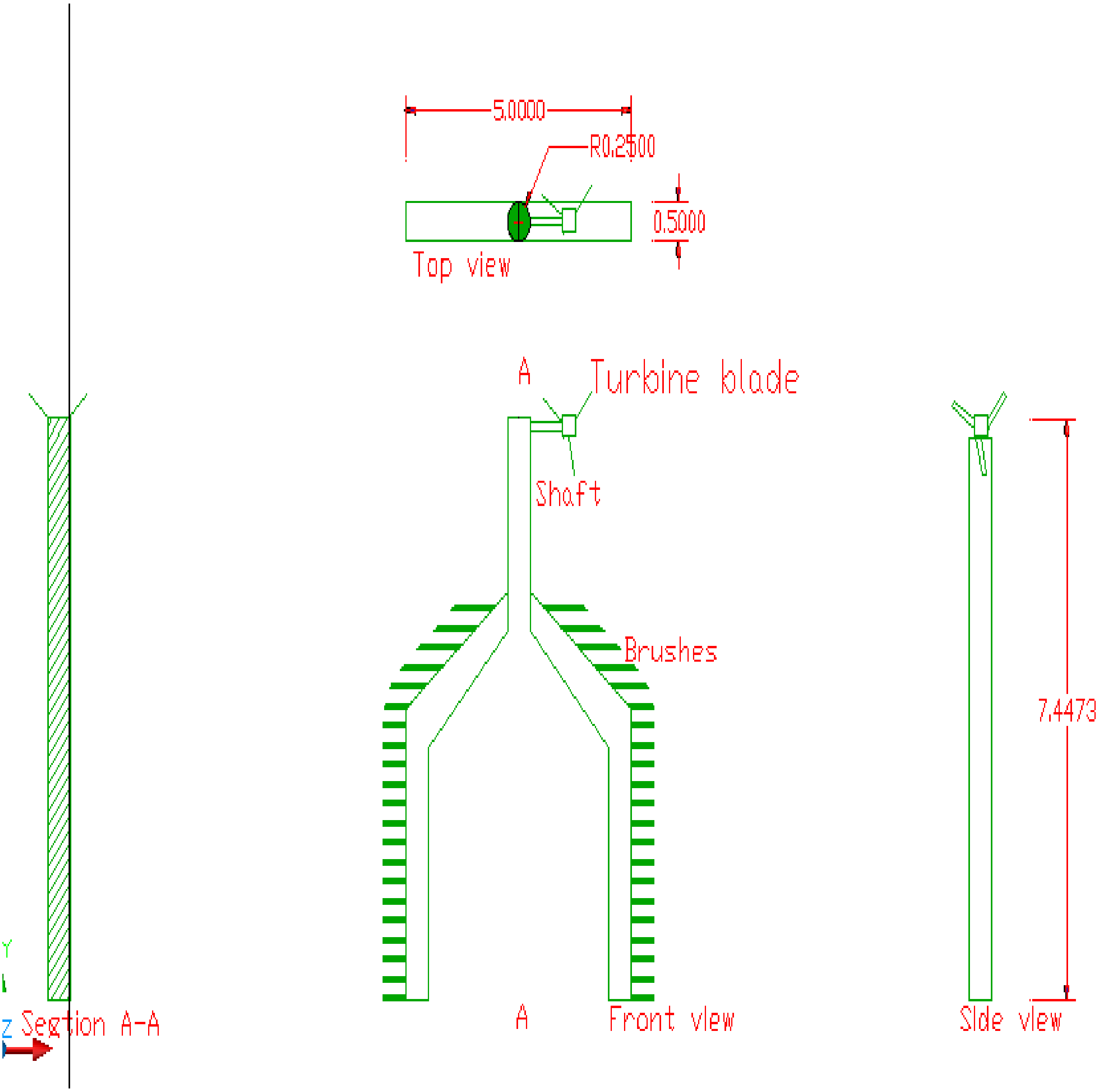


Figure 3. 1 Design drawing of possible solution 1

The solution is an in-built self-cleaning brush mechanism for a suction basket device. The mechanism is made up of stainless-steel brush bristles coupled to a hardwood body joined by a wooden shaft. A wind turbine provides power to the device. When a wind stream passes through the turbine, its three blades revolve. Brushes remove debris that accumulates on the filter element when a rotational force is applied. The assembled mechanism is placed in a cylindrical suction basket, connected to a pumping line, and immersed in water where the pumping takes place. The device has the disadvantage of being climate dependent, as the cleaning process is intermittent and so cannot work when there is no wind. When exposed to large flows, the gadget is weighty enough to tilt.

3.3 Possible solution 2(suction scanner)

The second possible solution is shown in Figure 3

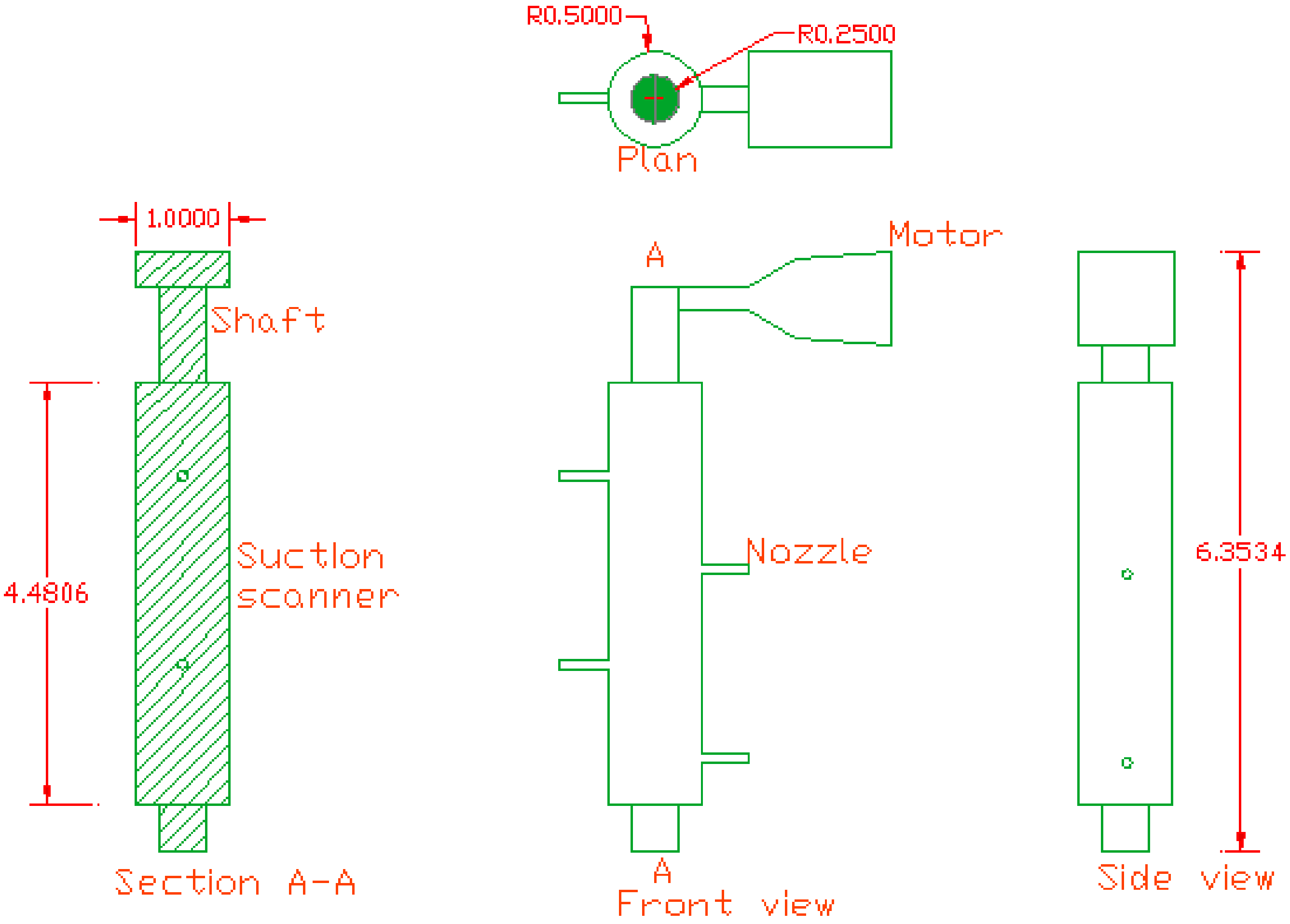


Figure 3. 2 Design drawing of possible solution 2

A suction scanning technology is the solution. The latter differs from the former due to the drive engine and functioning philosophy. It consists of nozzles, a suction scanner, a shaft, a control system, and a motor. The nozzles are constructed of polyethylene plastic, while the suction scanner is made of stainless steel. When a cleaning cycle is started, the iron shaft transfers torque from the motor. The self-cleaning cycle is triggered by the accumulation of filter cake on the screen surface as detected by the pressure differential. Filter cake is removed from the filter element by rotating water jets. However, the concept will not operate in places where the water is of poor quality. When dealing with large solids and high solids concentrations, suction scanning cannot avoid clogging and fouling. Backwash strainers cannot remove large materials and will clog, necessitating human removal of the solids and cleaning of the filter. It also has very intricate technology, which may significantly increase total prices, making it cost ineffective.

3.4 Possible solution3 (combined mechanism)

The third possible solution is shown in Figure 3.3

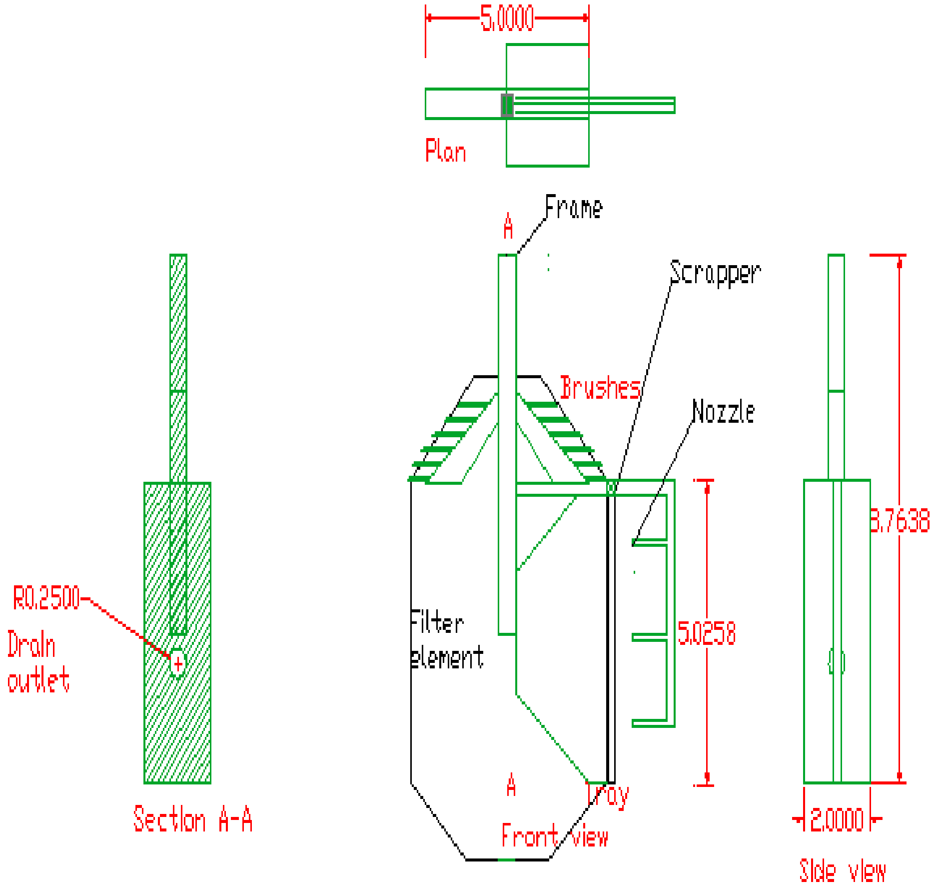

5.0000
Plan
Frame
A
Scrapper
Brushes
Nozzle
R0.2500
Drain
outlet
Filter
element
3.7638
5.0258
A
Tray
Section A-A
Front view
2.0000
Side view

Figure 3. 3 Design drawing of possible solution 3

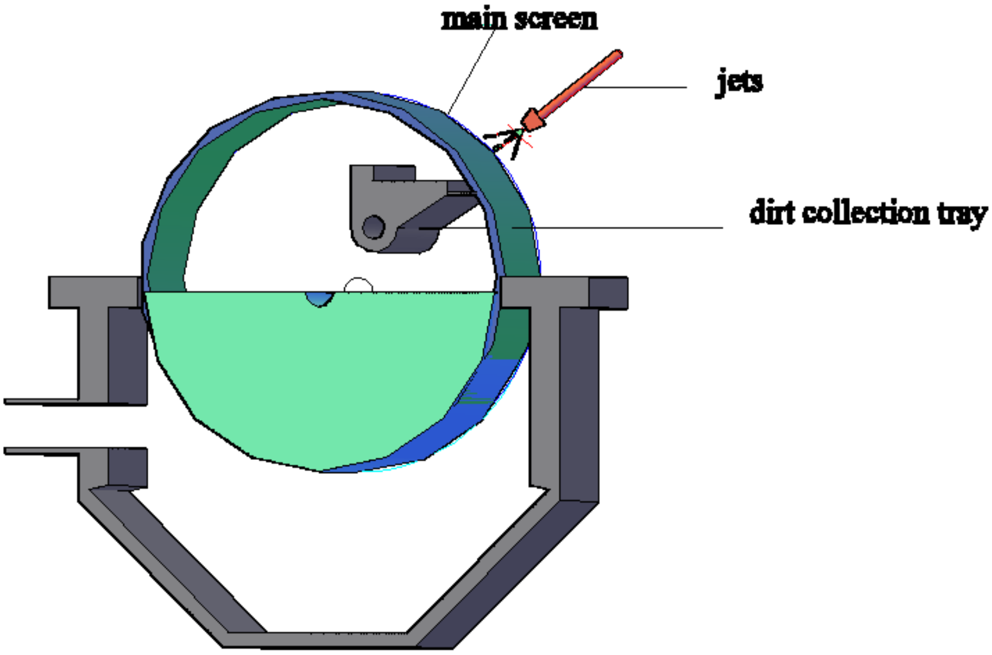


Figure 3. 4 Schematic diagram of the back flush mechanism

To compensate for the shortcomings of the first two options (combined cleaning mechanisms), the solution combines them. The mechanism is installed in a pump suction basket that is attached to the end of the pump suction line. Pumped water must pass through the screen before entering the pump intake line. The mechanism is stationary, but the filter element rotates. Flow turns the turbine propeller, which generates rotational force and is delivered via a sprocket. The mechanism is made up of nylon brush bristles linked to a plastic body with a concave contour. A rigid plastic scraper blade placed beneath the nozzles removes trash from the filter element. A 9.5 mm high-pressure hose feeds a triple back-wash nozzle, which continuously blasts away residual filter cake as the filter element rotates, into a collection tray, and finally out through a drain exit. Brushes with big mesh (60) clean the concave region of the filter element, while jets with mesh 20 work on the body. All of the components are mounted to a rigid square plastic shaft. HDPE is used to make the collection tray. Rubber seals around the perimeter of the collection tray prevent debris from escaping. Because of a combination of brush and flush-back movements, the design can manage both large and small particles. It is environmentally friendly because filter cake is directed to a disposal chamber where water is filtered and recycled.

3.5 Solution matrix

Solution matrix was used to evaluate possible solutions.

Table 3. 1 Design score matrix

Factor	Solution 1	Solution 2	Solution 3
Filter cake cleaning efficiency	70	65	90
Feasibility	90	60	90
Cost of manufacturing	90	55	85
Safety	70	80	70
Aesthetics	80	75	85
Stability	75	73	78
User friendly	70	75	80
Functionality	65	68	70
Ease of maintenance	70	65	65
Environmental impact	70	70	90
Total score	750	686	803

The chosen solution after the analysis was awarded to possible solution 3. The solution was further developed to significantly deal with the problem at hand

3.5.0 Design calculations

The final solution's capacities, sizes, and measurements are computed in order to have the perfect specifications of the material that must be acquired for the product to be obtained as designed.

3.5.1 Capacity

The filter is specially developed for medium to high flows of at least 60 m3/h, and it combines the benefits of high-quality filtering from irrigation applications with self-cleaning features to provide a continuous water supply.

3.5.1.0 Design of a debris collection tray

A hopper is a debris collection box that is designed to hold a debris-water mixture and transport it to the filtration chamber via the drain outlet. Because the drain outlet is vertically oriented in the bottom of the hopper, the hopper was constructed in the shape of a trapezoidal prism with an extended rectangular shape at the bottom to send the mixture to the drain outlet. The trapezoidal prism has a 300-degree angle of repose. As a result, the material utilized for the design of a debris collection tray is 4 mm thick HDPE sheet, and the formula for calculating volume is presented below.

Given that; $h = 0.235$ m

$d = 0.4$ m

$a = 0.5$ m

$b = 0.2$ m

$Wh = Mh \times g$ (1)

Where; Wh – weight of the hopper [N]

Mh – total mass of the hopper [kg]

g – Acceleration due to gravity which is 9.81

$Mh = Vh \times gh$ (2)

Where; Mh – mass of the hopper [kg]

Vh – volume of hopper [m^3]

gh – density of hopper [$\frac{kg}{m3}$]

$Vh = SAh \times Th$ (3)

Where; SAh – total surface area of the hopper [m^2]

Th – thickness of the hopper material [m]

SAh = total surface area of trapezoidal prism + total surface area of rectangular prism (4)

$A = L \times W$

$= 0.4 \times 0.2$

$= 0.08\ m^2$

$B = \frac{1}{2}h(a+b)$

$h = \sin\alpha \times H$

$= \sin 30^0 \times 0.235$

$= 0.118\ m$

$B = \frac{1}{2}(0.118)(.5+.2)$

$= 0.0413\ m^2$

$C = L \times W$

$= 0.2 \times 0.0585$

$= 0.0117\ m^2$

Total area = $0.08\ m^2 + 0.0413\ m^2 + 0.0117\ m^2$

$= 0.133\ m^2$

Volume of hopper = At

$= 0.133 \times 0.004$

$= 0.000532\ m^3$

Density of HDPE sheet = 970 kg/m^3

Mass of hopper = 0.516 kg

<u>Weight = 5.06 N</u>

3.5.1.1 Frame

The frame serves as a support system for the hopper and brushes. The frame was built using 20 mm 40 mm iron bars. The weight of the frame was determined as follows:

$Wf = Mf \times g$ (5)

Where, Wf – weight of the frame [N]

Mf – mass of frame [kg]

g – Gravity = 9.81

Mf = total surface area × density

Volume bar 1 = $500 \times 20 \times 40 = 400000$ mm^3

Volume bar 2 = $20 \times 20 \times 40 \times 2 = 32000$ mm^3

Volume bar 3 = $600 \times 20 \times 40 = 480000$ mm^3

Total volume = 912 000 mm^3

Density of iron bars = 7.85 kg/ m^3

Mass = $0.912 \times 7.85 = 7.16$ kg

<u>Weight of frame = 70.23 N</u>

3.5.1.2 Weight of the mixture

Volume of hopper = surface area × allowable height

$= 0.133 \times 0.118$

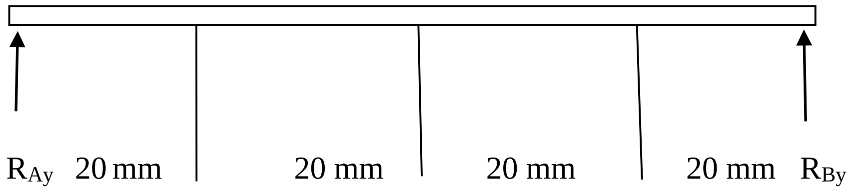
$= 0.0156$ m^3

Density of fluid = 997 kg/ m^3

<u>Weight = 152.85 N</u>

3.5.1.3 Maximum bending moment of machine

$0.5(W_1+W_2)$ N W_3 N $0.5(W_1+W_2)$ N



Where, W_1 – weight of hopper

W_2 – weight of frame

W_3v – weight of contents

$R_{Ay} + R_{By} = 0.5(W_1+W_2) + W_3 + 0.5(W_1+W_2)$

$R_{Ay} = 228.14 - R_{By}$ (1)

$\sum M_A = 0 = - 37.65(0.02) – 152.85(0.04) – 37.65(0.06) + R_{By}(0.08)$

$R_{By} = 114.08$ N

$R_{Ay} = 228.14 - 114.08$

$= 114.08$ N

$\sum M_A = -37.65(0.02) – 152.85(0.04) – 37.65(0.06) + 114.08(0.08)$

$= \underline{0.0004 \text{ Nm}}$

3.5.1.4 Design of scraper blade

Given that the filter element rotates at a lower speed of 3 rpm, it exerts 17.35 Nm torque. Because the scraping blade is parallel to the filter element and only a minor surface is in intimate touch with the suction basket, the blade should be linked to a fixed shaft. As a result, the force pushing on the shaft is

$$F = \frac{T}{Lsin\alpha}$$

Where, F – force [N]

T – Torque [Nm]

L – Length of the shaft [m]

Sinα – angle of contact [^{0}]

$= \frac{17.35}{0.4 sin 90}$

= 43.38 N

$T = \tau d^3 \frac{\pi}{16}$……………………………………………………………………………Khurmi (2005)

Assuming permissible stress of 42 MPa;

$d = (\frac{17.35(16)}{42\pi})^{0.333}$

= <u>13 mm</u>

3.5.1.5 Design of brush

Because nylon bristles are flexible, they transmit little to no force, yet they must be held in place by some means.

Force acting on the brush body ≤ 43.38 N.

Shaft size; $d = (\frac{17.35(16)}{42\pi})^{0.333}$

= 13 mm

Design of key

A key is essential to prevent relative movement of the shaft brush.

Length of key (L_k)

The length is at least equal to the length of the sleeve. The coupling key is made into two parts so that the length of the key sits in the way of each shaft.

L_k = L/ 2=3.5d/2= 22.75mm

Width of key (W_k)

W_k= d/4=13/4= 3.25 mm

3.5.1.4 Nozzle calculations

Orifice size = 1 mm

Flow rate = 0.39 l/min

According to Clearwater (2013), for under-water jet to be more effective, nozzle set distance should not exceed 0.0511 m away from the filter element.

Swath width at 120^0 spray angle: $\tan\alpha = \frac{0pposite(x)}{adjacent}$

Considering half triangle: $\tan 60^0 = \frac{x}{0.0511}$

$x = 0.0511 \tan 60^0$

$= 0.089$ m

Therefore, swath with = 2(0.089)

= 0.18 m

Total width to be covered = 0.4 m

Number of nozzles (n) = $\frac{total\ width\ to\ be\ covered}{swath\ width\ of\ one\ nozzle}$

$= \frac{0.4}{0.18}$

= 2.22

Take n = 3

Total flow rate = 3(0.39)

= 1.17 l/min

Volume of water back-flushed per hour = $\frac{discharge}{time}$

$= \underline{0.0702\ m^3}$

3.6.0 Pressure loss

Water pressure lowers as it travels due to changes in height, friction, and obstructions. When encountering a filter element, filters, or pipe couplings, high heights tend to diminish water pressure. Rough surfaces increase frictional forces, reducing water pressure. As a result, the design should constantly aim to limit pressure loss to a minimum.

3.6.1 Clean screen pressure loss

$\Delta P = G \times Cr(\frac{Q}{Cv})^2$……………………………………………………………….....(Titan, 2016)

Where, ΔP – change in pressure [kPa]

G – Specific gravity of the liquid

Cr – correction factor

Q – Discharge [m^3/h]

Cv – flow coefficient

For discharge of 60 m^3/h on 20 mesh lined basket;

$\Delta P = 1000 \times 1.2(\frac{60}{2190})^2$

$= 0.90$ kPa

For 60 mesh lined basket;

$\Delta P = 1000 \times 1.4(\frac{60}{2190})^2$

= <u>1.05 kPa</u>

3.6.2 Head loss in 9.5 mm pipe

$h_f = \frac{flv^2}{2gD}$ ……………………………………Darcy - Weibach formula (Douglas, 1980)

Where, h_f – head loss due to friction [m]

f – Frictional coefficient

l – Length of the pipe [m]

v – Flow velocity [m/s]

g – Force of gravity [N]

D – Pipe diameter [m]

Area, $A = \pi r^2$

$= \pi (0.00475)^2$

$^{=}$ 0.0000709 m^2

Given Q = 0.0702 m^3/h = 0.0000195 m^3/s

Velocity, v = $\frac{Q}{A}$

$= \frac{0.0000195}{0.0000709}$

= 0.28 m/s

Assuming f = 0.5, $h_f = \frac{0.5(6)(0.28)^2}{2(9.81)(0.0095)}$

= <u>1.26 m</u>

According to Douglas (1980), valves are inserted in pipelines to restrict flow by imposing significant head losses via the valves. Depending on how a specific valve is designed, a certain amount of energy loss normally occurs even when the valve is fully open.

$h_v = k_v(\frac{v^2}{2g})$

Where, h_v – head loss due to valve fittings [m]

k_v – valve fitting coefficient

Assuming k_v = 0.5, $h_v = \frac{0.5(0.28)^2}{2(9.81)}$

= 0.002 m

Therefore, total head loss in pump back flush = $h_f + h_v$ = 1.26 m

Overall head loss = $h_p + h_f + h_v$

= 1.05 + 1.26 + 0.002

= <u>2.31 m</u>

Conclusion

The developments of the chosen solution were incorporated into the design of the filter

CHAPTER 4

Design manufacture, assembly and maintenance

4.0 Introduction

The design explains the strategies used in the construction of a sediment self-cleaning filter for irrigation water. The best alternative design was chosen after a careful review of all viable alternatives, which will be discussed in this chapter. The design was based on the design process producing a developed solution that adequately answers the challenge at hand.

4.1 Design process procedure

- The development stage of a suction self-cleaning mechanism included the following steps: design synthesis.
- The best possible solution was chosen based on cleaning efficiency.
- Further development of the chosen solution to address the shortcomings of the solution. Calculations for capacity and functionality of the chosen solution.
- Material assignment and detailed drawings.
- Fabrication.

4.2 Feedback stage will incorporate the following;

Test of the equipment.

Start/ stop.

Adjustment and operation.

Total suspended solids (TSS) assessment of processed water.

4.3 Design brief

An effective filtration device that is simple to use will be conceived, sketched, built, and tested. The device should be able to manage a discharge of at least 60 m3/hr of water with total suspended solids less than 35 mg/l per hour.

4.4 Design specification

The design should have the following specifications that are critical to its ease of use, maintenance and costs;

Ease of cleaning and maintenance.

Durable material.

Reasonably affordable – assembled device should not exceed USD300.00.

Ease of operation.

Over-clogging protection

4.5 Morphological analysis

In designing the solutions, the morphological chart was utilized to identify components to be setup.

Table 4. 1 Morphological design chart

Components	**Solution 1**	**Solution 2**	**Solution 3**
Brush	Stainless steel bristles		Nylon bristles
Shaft/ keys/ gears	Plastic	Stainless steel	Iron
Sprocket			Mild steel
Drive	Manual	Motor, Programmable logic controller (PLC)	Turbine propeller
Debris collection tray			Plastic
Transmission	Shaft	Bevel/ shaft	Sprocket/ shaft
Nozzles		Copper	Plastic
Frame	Wood	Plastic	Iron

4.6 Material selection

The materials utilized in the development of a suction self-cleaning system should be readily available and inexpensive in order for the device to be cost effective. Furthermore, the material must be long-lasting and non-corrosive in order to outlast its use. As a result, the material was thoroughly examined to determine its suitability for the design.

Table 4. 2 Material selection

Component	**Material**	**Required features**
Brush	Nylon bristles	Non-corrosive, rough and flexible
Shaft/keys/sprocket gears	Iron	Rugged and durable
Chain sprocket	Mild steel	Light and rugged
Nozzles	Plastic	Non-corrosive
Collection tray	Plastic	Light and non-corrosive
Frame	Iron	rugged and durable

4.7 Design regulations and specifications

Table 4. 3 Specification of brush

Specification number	**Particulars**	**Details**
1	Filament material	Nylon
2	Brush width	230 mm
3	Filament diameter	3 mm

Table 4. 4 Specifications of scraper blade

Specification number	**Particulars**	**Details**
1	Scraper material	Plastic
2	Scraper length	400 mm
3	Scraper width	30 mm

Table 4. 5 Specifications of back flush nozzles

Specification number	Particulars	Details
1	Nozzle material	HDPE
2	Flow rate	0.25 l/min
3	Diameter	5 mm

4.8.0 Prototype construction

The development of the chosen solution will include design calculations and material selection.

4.8.1 Cutting

Steel elements and sheet plastic material are trimmed to size for fabrication dimensions. Cutting disks mounted on a hand grinder, a power saw, and a guillotine will all be employed.

4.8.2 Sheet plastic

The lengths are calculated correctly. The measurements are then drawn on the sheet with a scribing instrument (divider). The markings are then utilized as a guideline for cutting.

4.8.3 Drilling

To secure the components with bolts and reverts, holes must be drilled using a hand drill.

4.8.4 Welding

Welding the bars that make up a frame is the primary metal element jointing method. Arc welding would be done with welding rods.

4.9.0 Testing of the prototype

Following the fabrication process, the prototype would be tested immediately. Testing is performed to assess the system's performance in relation to the design specifications. The machine functionality is an important stage; the test works to establish machine performance and debris cleaning effectiveness.

4.9.1 Testing procedure

The suction self-cleaning filter would be tested shortly after manufacturing. The filter would be subjected to a component inspection using nondestructive testing procedures.

Filter test;

1. The filter would be subjected to visual inspection as well as testing in water of variable quality and discharge rates ranging from 40 m3/h to approximately 250 m3/h. The rotating speed of the filter element would be adjusted in order to determine the influence of speed on filter performance.

2. The filtering time would be examined as well.

3. Head loss throughout the brush, scraper, back flush nozzles, and overall would be determined.

CHAPTER 5

PROJECT EVALUATION

5.0 Results

5.1 Filtering time

The prototype was submerged in a flowing water channel. The water flowed at a consistent rate. According to the information acquired, filtration time is minimal during the initial operation and increases when the concentration of solids grows owing to water quality issues. This is due to the fact that as the concentration of particles in the suspension increases, so does the thickness of the filter cake, decreasing the rate of filtration. The change in filter element rotation caused a considerable difference. Lower speeds tend to provide better results, and vice versa. Figure 5.1 depicts how speed influences water filtering time. High-speed filters require fine water to avoid premature filter element clogging.

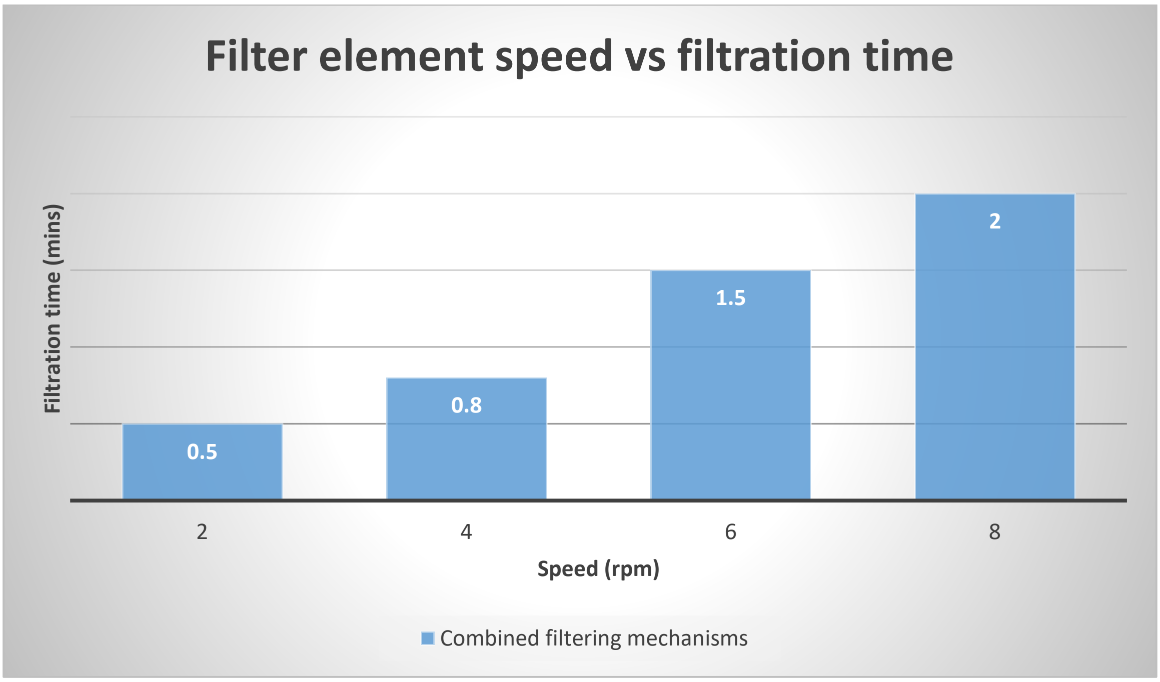


Figure 5. 1 Speed and filtration time variation analysis

5.2 Quality of filtration

Using a variable pump output, samples of filtered water were collected and evaluated for quality. The results reveal that low discharges produce samples with few TSS of less than 35 ml/l, and vice versa.

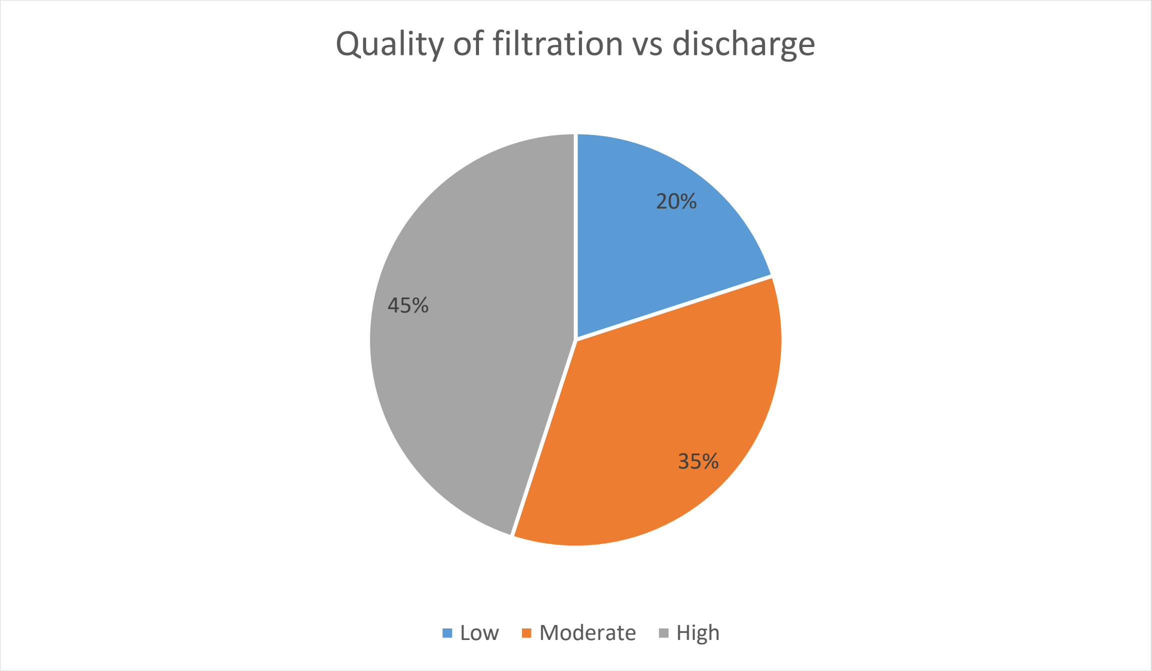


Figure 5. 2 Quality of filtration against discharge

The figure 20% indicates in blue that with modest pump discharges of little more than 60 m3/h, TSS is as low as 20% (35 ml/l). Moderate flows produce 35 TSS 100, but heavy discharges (more than 200 m3/h) produce TSS of 45% (> 100 ml/l). This is because the increased sucking impact has a wide coverage, giving the cleaning mechanisms little opportunity to blow off debris.

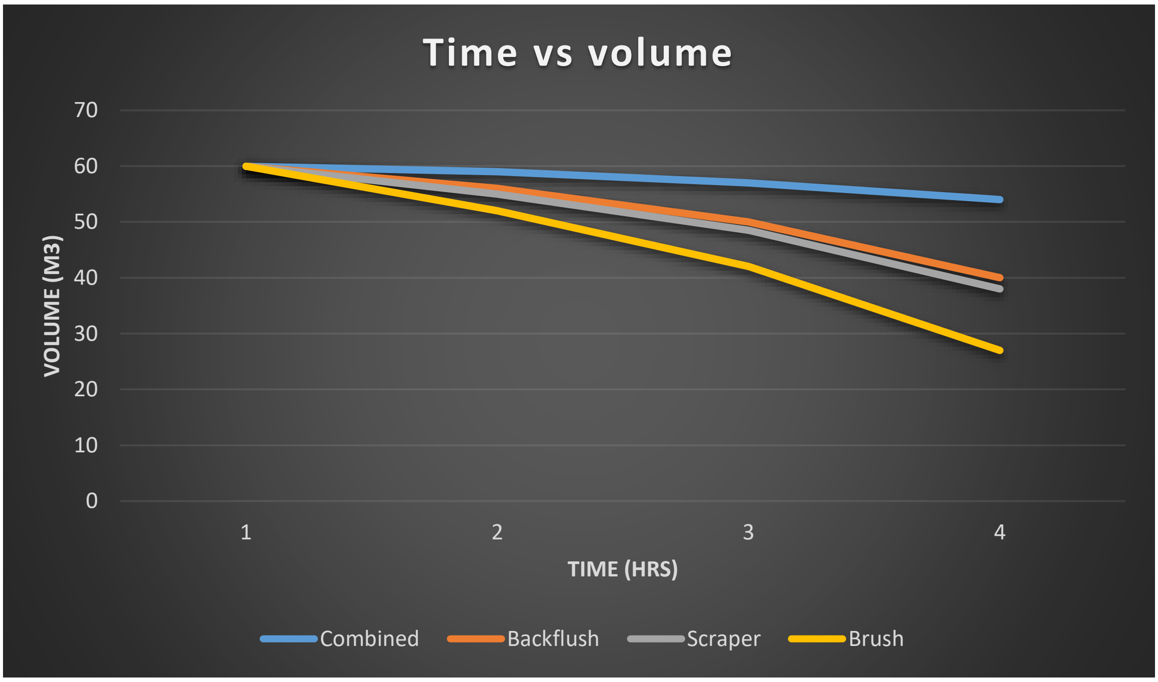


Figure 5. 3 Flow with respect to time

For the combined cleaning methods, the volume of filtered water is practically constant. This is due to the combined impact of the back flush, brush, and scraper as filter cake is wiped off at each region of the filter element. Back flush and scraper had small discharge deviations due to their combined effect because they function hand in hand as debris escaping from the scraper blade may be blasted off by the strong water jets. The rate of flow decreases with time due to partial closure of the filter element and pressure drop across the brush cleaning mechanisms, as shown in Figure 5.3.

5.3 Discussion

Depending on the parameters of interest, the gadget was subjected to various situations. The velocity of the stream was initially constant and then adjusted to investigate the influence of filter element speed (2 rpm - 8 rpm) on filtering time. As a result, when the speed is high, it takes more time to efficiently remove filter cake than when the speed is low. The pump discharge was then varied to determine the amount of TSS on the outflow, and the findings suggest that high discharges are subject to high TSS of more than 100 ml/l. As a result of the partial closure of the filter element when filter cake forms, the volume of filtered water reduces as operating time increases. Overall, the pump suction basket's self-cleaning filter was the best option. Water was treated in the following order: filtering duration, filtration quality, and head loss. According to the results, the combined cleaning mechanism produces the greatest results in terms of reduced filtering time and enhanced filtration. As a result of the testing, it is a fact that the device works and can be operated with reasonable ease, while remaining structurally sound and safe.

5.4 Material cost

It is divided into two parts: the material used to make the machine and the material used to make consumables.

5.5 Bill of materials

The materials used for the fabrication of a sediment self-cleaning filter are listed and coasted herein Table 5.1.

Table 5. 1 Cost of materials

Item description	**Dimensions**	**Unit cost ($, USD)**	**Quantity**	**Total cost ($, USD)**

HDPE sheet	4 mm thickness × 1000 × 1000 mm side dimensions	15.00	1	15.00
Nylon bristles	2 mm diameter	5.00	4 sets	20.00
PE nozzles	1 mm diameter	7.50	3	22.50
Plastic square solid shaft	1000 × 30 mm	7.00	3	21.00
Couplings and accessories (nylon connectors, valves, glue, nails, hose clamps)				40.00
High-pressure plastic pipe	9.5 mm diameter and 6000 mm long	40.00	1	32.50
Drain pipe	50 mm diameter	10.00	1	10.00
Hollow copper pipe	20 mm diameter and 1000 mm long	10.00	1	10.00
Iron bar	1500 mm long, (20×40) mm size	29.00	1	29.00
Total				200.00

5.6Cost of consumables

This is the cost of the consumable materials utilized in the costing.

Table 5. 2 Cost of consumables

Description	**Quantity**	**Unit cost ($, USD)**	**Total cost ($, USD)**
Welding rods	1 kg	2.50	3.00
Cutting discs	5	2.00	10.00
Grinding discs	2	7.00	14.00
Drill bits	2	7.00	14.00
Paint	1	5.00	5.00
Total cost			46.00

5.7Labour costs

Involves human efforts associated with the fabrication of a sediment self-cleaning filter. The cost of the labour was $40.00

5.8 Total fabrication costs

The sum of the costs was tabulated and added so as to get the total cost of the design

Table 5. 3 Manufacturing and operational cost

Cost characteristic	**Cost ($, USD)**
Material cost	200.00
Consumables cost	46.00
Labour cost	40.00
Total cost	286.00

5.9.0 Analysis of investment

The following factors are used to establish the market price of the product.

VAT = 15 %

PM = 15 %

Total cost = USD286.00

Selling price = total manufacturing cost + Value added tax (%) + Profit margin (%)

= TMC + VAT + PM

= 286.00 + 42.90 + 42.90

= USD371.80

Conclusion

The investment is worthwhile because the payback period is quite short and the gadget is cost effective, costing 2.51 times less than the total cost of utilizing a standard screen.

CHAPTER 6

Recommendations, Further Work and Conclusion

6.0 Recommendations

The self-cleaning suction basket is ideal for small to medium-scale farming. This is due to its adaptability to both small and medium discharge pumps. Due to its simple construction, the gadget can be used for purposes other than irrigation. It is straightforward to fix and maintain with excellent repair and maintenance practices. It has a relatively lengthy service life. The rear flush mechanism should be created to use an actuator to make operation even easier and more energy efficient. The information gathered is critical in demonstrating that the entire equipment will be mass built for commercial use in both farming and industry. The prototype developed should be fully finished with the use of stainless or galvanized steel for commercial use and production in order for the students to collect viable information on the economics and scientific performance of the machine.

6.1 Summary

The self-cleaning filter has an efficiency of 80% on average and a flow rate of at least 60 m3/h.The filter cake was cleaned from the filter element using a mix of methods including back flush, brush, and scraper. Debris that cannot be removed with a scraper blade might be jet blasted into a 4 mm HDPE cylinder and discharged through a 50 mm drain valve. Because some filter cake cannot be completely removed, the volume of filtration drops significantly with increasing running time. . The equipment works beyond a reasonable doubt and is extremely safe to operate with minimal labour and maintenance requirements. It is quite versatile in that it may treat water for use other than irrigation. It can also be used in other treatment operations such as water reticulation and sewage treatment. The suction basket machine is a highly profitable piece of water filtration and purification equipment. It was created using locally available materials, technology, and techniques, making it a substantial contribution to traditional approaches.

References

1. Advantech. (2006). Bag filters.

Benham, B and Payero, J. O. (2001). Filtration and maintenance considerations for subsurface drip irrigation.

2. Bucks, D. A and Nakayama, S. F. (1991). “Injecting of fertilizers and other chemicals for drip irrigation”. In proceedings of the Agri-Turf Irrigation Conference, Houston, Texas, 166-180. Silver Spring, MD.
3. Bucks, D. A and Nakayama, S. F and Gilbert, R. G. (1979). Trickle irrigation water quality and preventive maintenance. Agricultural Water Management, 2(2), 149 – 162.
4. Capra, A and Scicolone, B. (2004). Emitter and filter tests for wastewater reuse by drip irrigation. Agricultural Water Management, 68(2), 135 - 149.
5. Capra, A and Scicolone, B. (2007). Recycling of poor-quality urban wastewater by drip irrigation systems. Journal of Cleaner Production, 15 (16), 1529-1534.

6. Chapman, D. (1996). Water quality assessments – a guide to use of Biota, sediments and water in environmental monitoring, second edition. Chapman and Hall, London, 191 – 193.
7. Clearwater. (2013). Suction self-cleaning strainers.
8. Dhaka, A. K. (2006). Insufficient irrigation facilities in arid and semi-arid areas are two major challenges in crop production.
9. Dimir, V and Damla, U. E. (1994). Determination of the efficiencies of different types of filters and filter combinations used in drip irrigation system in open channel.
10. Dimir, V., Yurdem, H and Yazgi, A. (2009). Determination of head losses in metal body disc filters used in drip irrigation systems.
11. Douglas, J. F. (1980). Solving problems in fluid mechanics. Volume ELBS.

12. Duran-Ros,, M., Puig-Bargue, M., Arbat, J., Barraga, J and Ramirez, F. (2009). Performance and backwashing efficiency of disc and screen filters in micro irrigation systems.
13. Duran-Ros, M., Puig-Bargue, M., Arbat, J., Barraga, J and Ramirez, F. (2014). Effect of filtration level and pressure on disc and screen filter performance in micro irrigation systems using effluents.
14. EPA. (1995). Factors affecting water filtration and straining.
15. FAO. (2000). Development of irrigation schemes in Zimbabwe as a famine relief strategy.
16. FAO. (2012). In a farm setup, water extraction is continuous such that there is limited time to clean the suction screens.
17. Gajbhiye, V., Ahmad, N and Tufail, S. M. (2018). Design and application of DC vacuum cleaner using axial flow fan.
18. Gordon, B. (2018). Nozzle design and function, volume 03.
19. Hillie, J. (2007). Nanotechnology and the challenge of clean water. Nature nanotechnology. 2- 663-664.
20. Hoko, Z. (2008). An assessment of quality of water from boreholes in Bindura district, Zimbabwe, Phys. Chem. Earth, 33, 824 – 828.
21. Hunt, J. A. (2001). Filtration media: Making the right choice. Water conditioning purification magazine.
22. Joseph, L. (2006). Pressure vessel design, first edition.
23. Khurmi, R. S and Gupta, J. K. (2005). A textbook of machine design.
24. Lawson, E. O. (2011). Physico – chemical parameters and heavy metal contents of the water from the mangrove swamps of Logos lagoon, Logos, Nigeria, Advances in biological research, 5, 8 – 21.
25. Liu, H. F., Zheng, T. G., Liu, F and Zong, Q. L. (2010). Analysis of filtering time and sewage time for automatic suction screen filter.
26. Marcus, A. N. (2005). Amiad self-cleaning strainers for water filtration. Oxnard, CA 93030.
27. Matteson, J. (1987). Filtration principles and practices; gas filtration theory in second edition (ed.) pp28-32.
28. Msh. (2006). Water is a scarce, limited and precious resource and one of the most expensive inputs in agriculture.
29. Parksanfilters. (2010). Filtration theory and practice.

30. Patel, R., Oron, G., Shelef, G and Tarzynski, B. (1979). Trickle irrigation using treated