Design of an Automated Lime Dosing System for Bulawayo Mining Company Zimbabwe

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Abstract

Lime can be hazardous to human health if inhaled. Workers are exposed to airborne lime particles with the current dosing system as they manually add lime from 25kg bags onto a moving conveyor belt during gold processing. A dosing system is essential to accurately and consistently add precise amounts of substances to various processes or products. Manual dosing systems frequently run into several technical issues too, such as inaccuracies, inconsistent results, operator mistakes, security issues, and problems with monitoring and control. By using an Arduino microcontroller to create an automated lime dosing system for Bulawayo Mining Company, this research project addressed these problems. To create a program that enables the microcontroller to communicate with various sensors and hardware elements, the Arduino IDE software is used. A pH sensor, an ultrasonic sensor, a servo, a liquid crystal display (LCD), and a DC pump are some of the components of the circuit. The DC pump automatically activates to bring the pulp's pH value back to 9 when the pH level rises above a predetermined threshold. The LCD shows the pH readings and the water level, giving operators access to information in real time. This research presents the design and implementation of an automated lime dosing system using an Arduino microcontroller to address the issues with manual dosing systems. The system reduces downtime, offers precise and consistent dosing, and prevents operator exposure to lime. By using lime in solution form, the solution also benefits the environment.

Keywords
Arduino microcontroller, Automated dosing, Dosing system, ,Environmental-friendly dosing

1.Introduction
In the gold processing industries, lime is crucial. Despite its significance, it poses numerous concerns. The operator in the dosing process faces numerous health dangers while applying lime, including the possibility of being grabbed by a moving conveyor belt. This project aims to draw attention to all the drawbacks of the current lime dosing system while also considering the health of the operator, neighboring workers and the environment. Lime reagents are consumed largely in the gold processing industries. Its acts as a pH control agent for optimal cyanidation leaching of gold as a neutralization agent. A range of conditions upstream of cyanidation influence lime consumption and functionality of the overall process. Cyanidation is extracting gold or silver from their ores using the cyanide process. (Law Insider Inc. 2013-2022). In most cases the quantity of lime consumed depends on factors like

- Lime reagent properties
- Methods of preparation
- Gold ore type
- Processing flow sheet

Lime is an odorless white granule. Lime, which can be calcium hydroxide or calcium oxide, is a frequently used reagent for modification. Its classification is that of an inorganic modifier and its primary function is to alter the pH of the pulp. (Bulatovic 2007). The properties of Lime in terms of its chemistry can be found in Table 1.

Table 1. Chemical Properties of Lime (Kimberlite Softwares Pvt. Ltd, 2022)

Appearance	Soft white powder/ colourless liquid
Basicity	2.37
Chemical composition	Calcium oxide→calcium carbonate→ metallurgical coke
Density	2.211g/cm3 ,solid
Melting point	512 degree Celsius
Molar mass	74.093g/mol
Molecular formula	Ca(OH)2
Other cations	Magnesium hydroxide, strontium hydroxide , barium hydroxide

For direct cyanide leaching, a procedure called 'lime dosing' involves adding lime and water to crushed ore in a mill. This process helps milling at the proper solids concentration and viscosity. At a rate of 0.5-2kgof lime per ton of dry feed, lime is added. The number of acid-consuming processes and the needed pH control accuracy determine how much lime dosing reagent is used in gold processing plants. Dry quicklime is directly applied to ore on a conveyor belt at the Bulawayo Mining company. This technology is appropriate for ore with low lime consumption (2 kilogram per ton of ore treated). The same procedure is applied in gold heap leaching operations, when dried quicklime is immediately dosed onto a truck's rear. These procedures do not offer accurate pH regulation or permit pH correction after adding lime to the ore. For flexible and precise pH control, dry quicklime is slaked in most gold processing applications to provide a suspension of Ca(OH) particles that can be pumped and dosed into various processes. Ball mill slakers, detained slakers, and stirred slakers are a few examples of the several reactors that can be used to achieve slaking.

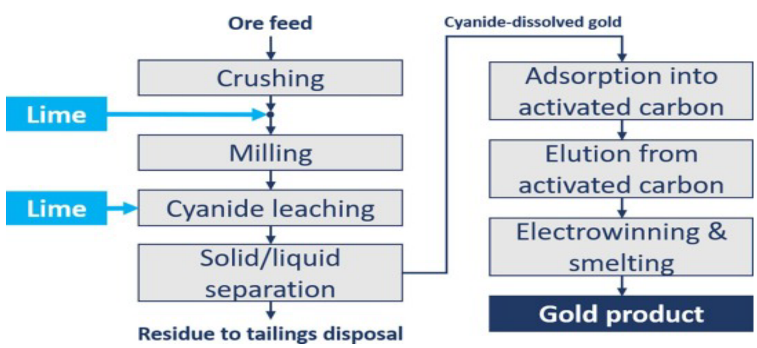

Figure 1. Simplified block diagram of mining process (Lambert, Ingram and Eksteen, 2021)

The block diagram on Figure 1 is a common example of ores with a gold grade of approximately >1g of gold per ton of ore. It contains low levels of iron and copper sulfide minerals that do not hinder processing by increasing cyanide consumption. Bulawayo mining company uses hydrated lime, which is added to the system. Operators add lime to the milling plant from 25kg bags onto a moving conveyor belt exposed to the air as shown in figure 2. Hourly additions of 75kg of lime require operators and all other employees working in the milling plant to stop what they are doing and leave the facility for a safer location because airborne lime dust is produced during this operation. Due to insufficient communication mediums, some employees may not hear the call to add lime and become victims of the silent killer. Prolonged exposure to impure lime containing 3% to 20% quarts can increase the risk of silicosis. The manual lime dosing process shown in figure 2 is inefficient, inaccurate and poses safety hazards to workers. The process requires frequent monitoring, which leads to increased labour costs and potential errors. The imprecise dosing of lime can negatively impact the quality of the end product leading to potential financial losses.

Figure 2. An operator pouring lime powder onto a moving conveyor belt

The main aim of any mine is to produce a safe environment for the employees and those around them. An automated lime dosing system can significantly increase the efficiency of the lime dosing system. Automation can reduce the need for manual intervention, which saves time and reduces the likelihood of errors. This would increase productivity and throughput, ultimately improving the bottom line. An automated dosing system can provide highly accurate and consistent dosing, improving the product's quality. This is very important in gold processing, where even small variations in lime dosing can significantly impact the final product. Handling time can be hazardous, as it is highly alkaline and can cause chemical burns and respiratory issues. An automated system reduces the risk of exposure by minimizing the need for manual handling and providing a more controlled dosing process. When lime is applied, all those working in the milling plant must move to a safer location to escape the air-borne lime, increasing the downtime. This project seeks to show how unreliable the current method of lime dosing is and provide an efficient solution. The main aim of this project is to design an automated lime dosing system for The Bulawayo Mining Company gold processing plant. The objectives of this research are: to design an automated system that reduces the operator's chemical handling, to design a project that meets the international health and safety management standards of Mines(ISO 18001) which outlines the requirements for an effective health and safety management system and to design a system that doses lime more efficiently with a flow rate of 0.53, an improvement of the current system by also providing a prototype.

2. Literature Review

Dosing is adding a specific amount of a substance, such as a chemical or medication, to a process or product is done using a dosing system, a device, or system. Dosing systems are used in industry, agriculture, pharmaceuticals, and water purification. Dosing systems are employed in treating water to eliminate contaminants and make it safe for consumption. These chemicals added to the water include chlorine, fluoride, and coagulants. Dosing systems can be used in agriculture to apply nutrients and insecticides to crops to promote growth and ward off illness. Dosing systems can be used in the pharmaceutical industry to add exact dosages of medication to capsules or tablets. The sophistication of dosing systems can range from straightforward gravity-fed systems to highly automated systems that precisely manage the dosage rate using sensors and controls. Some dosing systems could also contain monitoring and control tools like pH sensors, flow meters, and controllers to guarantee that the dosage rate is precise and reliable.Dosing systems ensure that the desired amount of substance is added to the process or product, improving quality, efficacy, and safety overall. They are a crucial part of many industrial processes.

2.1 Lime use in mineral processing industry

Large amounts of lime reagents are used in the gold processing industries. Its purpose is to act as a neutralizer and a pH control agent for the best cyanidation leaching of gold. The general word for the reagent's numerous forms is "lime"(du Plesis and Naldrett, 2001). Among the formats are quicklime, a dry reagent mostly composed of calcium oxide (CaO), and component, created by oxidizing limestone that contains calcium carbonate (); hydrate or hydrated lime, a dry reagent made from the stoichiometric hydration of quicklime with water and mostly consisting of ; and slaked lime, also known as milk of lime, a slurry of ; `321`321particles typically in the range of 10 to 25 weight percentile though customized product formulations may contain up to 45%wt solids content, slaking quicklime in a stoichiometric excess of water. All other kinds of lime reagent, including quicklime (with active ingredient CaO), are made by oxidizing limestone (); at temperatures between 900 and 1300 C while employing a variety of kiln types and fuel sources (Pringer 2017). Calculations are typically contracted out to lime-producing enterprises distant from the mining site. The characteristics of quicklime are heavily influenced by the conditions of pyrolysis and the type of fuel used as an energy source during production (Boynton, 1980). These factors impact the porosity, reactivity, slaking properties, and ultimately the particle size of quicklime after reacting with water (Zanin and Plessis 2019). Although lime is generally inexpensive as a raw material, transportation logistics can be a significant cost component due to the remote locations of most mining sites. Quicklime, having a lower mass per unit of a reactive component to hydrated and slaked forms, is often preferred for long-distance transportation.

2.2 Dry quicklime versus slaked lime reagent use

The number of acid-consuming procedures and the degree of pH control required influence the application of lime reagent in gold processing. A dosing screw attached to a lime silo disperses der quicklime (with a particle size of 25mm) into the conveyor-belt feeding the ball mill in a simple dosing configuration. A feedback mechanism based on pH readings in the cyanidation process unit controls the dosing screw feed rate. When the amount of lime required to process the ore is predictable, consistent, and relatively modest (i.e., 2 kilograms per ton of ore handled), this dosing approach is frequently used. The method is predicated on the idea that the ball mill offers enough agitation and residence time for quicklime to quickly slake (or hydrate) into Ca (OH). In gold heap leaching processes, a similar dosing method is used, where dry quicklime is given directly to the ore on the back of a truck before the ore is stacked into a heap. (Kappes 2002).

2.3 Automation

According to Benhabib (2003), automation refers to utilizing information technologies and control systems to reduce the dependence on human labor in producing goods and services. Unlike mechanization, automation not only deals with the physical aspects of industrialization but also reduces the need for human cognitive abilities. On the other hand, mechanization primarily assisted human workers with the physical demands of labor. The primary aims of automation control systems in industries are to enhance productivity, improve product quality, and manage production costs.

2 .4 Control Concepts system

Two main control systems are utilized when analyzing and designing modern process control systems: open and closed-loop.In an open loop control system, the control action is not affected by the output, meaning that the output is unrelated to the input. Feed-forward control aims to identify and compensate for disturbances before the controlled variable deviates from the desired set point. The general method involves directly measuring the disturbance and taking appropriate control measures to mitigate its impact on the output of the process, as Bequette (2003) explained. Figure 3 illustrates the block diagram of a feed-forward control scheme.

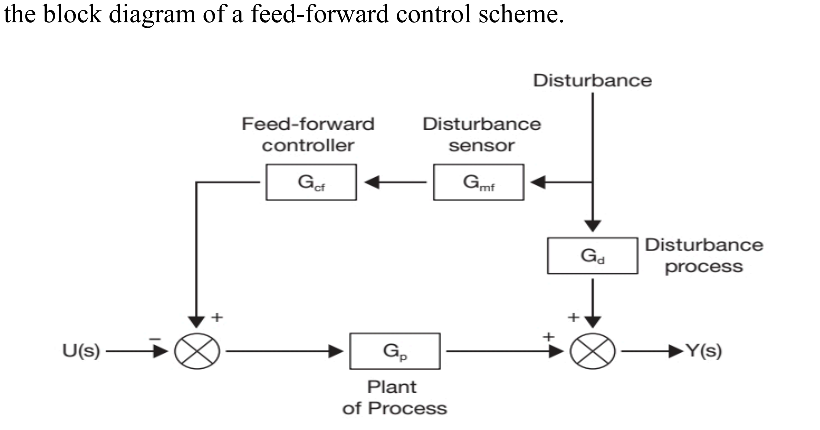

Figure 3. Feed forward control (Bequette, 2003)

Figure 4 is an instance of a chemical addition pump with variable speed control. The rate at which the chemicals are fed into the system to maintain its optimal chemistry is determined by an external operator. If the system's chemistry changes, the pump cannot automatically adjust its feed rate without the operator's intervention. The benefit of this system lies in its simplicity of design. However, the drawback is that the open-loop control system does not allow the input to influence the output or controlled variable.

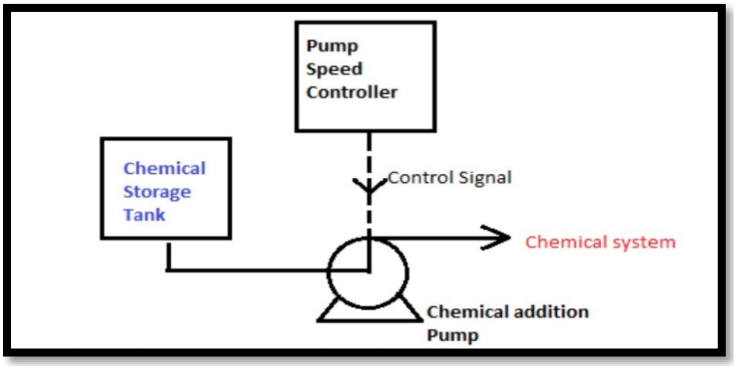

Figure 4. Open loop control system

A mechanical or electronic device known as a closed loop control system automatically adjusts a system to maintain a desired state or set point without the involvement of a human. It employs a sensor or feedback system. The block diagram representation of a closed-loop control system is shown in Figure 5.

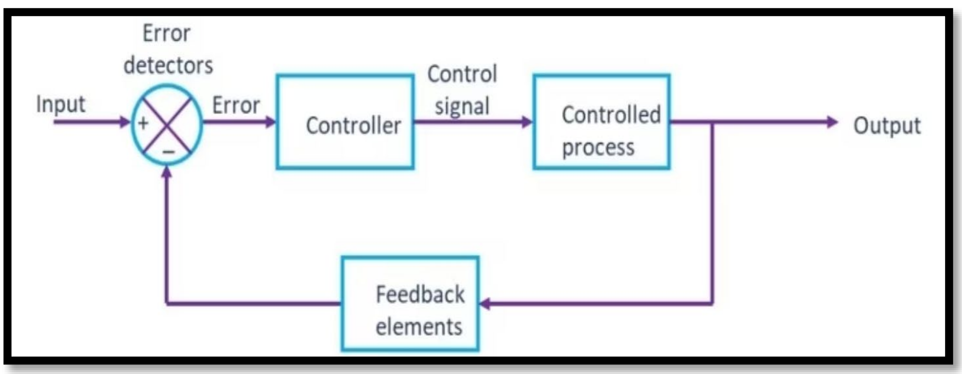

Figure 5. Closed loop control system block diagram (Parasher, 2022)

The closed loop control system's precise and efficient output is a result of the feedback structure. We give up some system characteristics to achieve this advantage. The main advantage is the automatic error correction aspect of closed-loop control systems, which makes them more independent or less reliant on human oversight. Additionally, compared to an open loop control system, it may stabilize an unstable system, enhance or reduce system sensitivity based on user requirements, and respond to outside disturbances more effectively according to Parasher (2022). It is possible to employ a feedback system in conjunction with a feed-forward system to avoid the challenge of anticipating the load disturbance. Therefore, the controller in this control system would get the combined input from the feed-forward and feedback system. Figure 6 illustrates the integration of feed-forward and feedback control. The feed-forward controller aims to minimize or eliminate the impact of external disturbances on the system. At the same time, the feedback control loop is a basic closed-loop control mechanism that responds by adjusting the set point, according to Bequette (2003). The combination of these two approaches results in superior performance compared to the simple feedback control, particularly in the presence of disturbances that can be measured before they affect the output of the process.

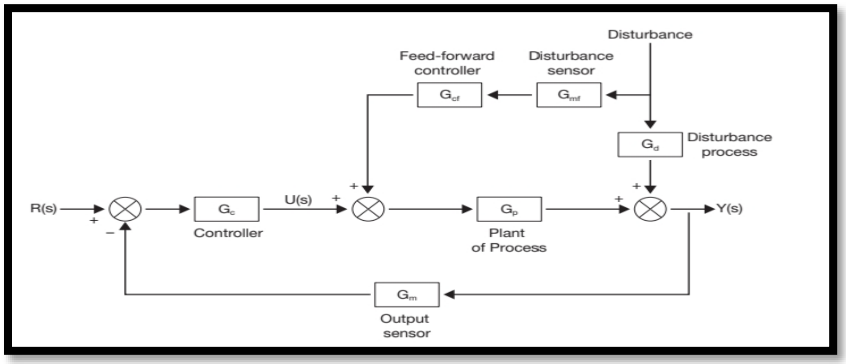

Figure 6. Feedback plus feed-forward control (Bequette, 2003)

2.5 Types Of Controllers

PID Controller

The PID controller, sometimes called a three-term controller, employs three primary control actions: proportional, integral, and derivative. These control actions are combined to produce a single control output. The PID controller is widely used in various control systems because it is straightforward to set up and implement. The output from a PID Controller is given as

$$u(t) = K_C\left(e(t) + \frac{1}{\tau_I}\int e(t)\,dt + \tau_D\frac{de\,(t)}{dt}\right) \qquad (1)$$

Where u(t) is the control signal, e(t) is the error signal defined as the difference between the set point and the output.

K_C =Proportional gain

τ_I =Integral time

τ_D =Derivative time (Astrom & Hagglund, 1995)

PLC Controller

A programmable logic controller (PLC) is a compact computer that has ports for data input and output commands. Its main function is to regulate a system's operation by analyzing input device status and determining how to control output devices using customized programs. Many businesses worldwide use PLCs to automate crucial procedures. PLCs receive inputs from various sources, such as automated data collection points and human input points, including buttons and switches. Based on their programming, PLCs decide whether or not to modify the outputs, which can control a variety of machinery, such as motors, solenoid valves, lighting, switch gear, safety shut-offs, and more.

2.6 Dosing Pumps

Dosing and metering pumps inject a chemical into a tank or pipe containing the dosed fluid after drawing a specific volume of liquid into its chamber. It is driven by an electric motor or an air actuator, and it features a controller that controls the flow rate and turns the pump on and off. More advanced control mechanisms are included in some models (All-Pumps, 2022). Dosing pumps are positive displacement oscillating pumps intended to inject a range of media into a process at a highly precise flow rate. Dosing pumps include peristaltic pumps, lobe-type pumps and diaphragm pumps.

Peristaltic Pumps

Peristaltic pumps use a flexible tube to transport the product. This tube has a semi-circular cross section. Due to their simplicity in sterilization and the ease with which the pump mechanism may be replaced if it becomes contaminated or broken, these pumps are extensively employed in the medical sector. Peristaltic pumps are incredibly precise. They can only withstand pressures up to the burst pressure of the flexible tube discussed before; therefore they quickly wear out and can't manage pumping into a high-pressure stream (Xie, Lin Q, & YC 2004)

Diaphragm Pump

The diaphragm pump gets its name from the RUBBER MEMBRANE it employs to carry out its pumping action. Air displacement is the basis for the diaphragm's operation. The membrane is mechanically pushed into and pulled out of a pumping chamber. When the diaphragm chamber collapses, all of the air is released. When the diaphragm is extended, slurry or whatever else is being pushed is drawn into the diaphragm chamber through the intake line. The EXPULSION or DISCHARGE STROKE, which is the INDUCTION or SUCTION STROKE, merely causes the diaphragm to collapse again. The sludge will be discharged through the discharge line. One-way valves will be used on the intake and exit lines to control the suction and discharge. The material is only accessible from the right line. The discharge valve will remain closed throughout the induction, or suction, stroke thanks to the vacuum. During the discharge stroke, the one-way valve on the intake line won't open. This pump can be utilized in multiple applications because it has an air motor (Michaud 2015).

2.7 Applications of automated dosing systems

Automated dosing systems are employed across multiple industries to precisely and effectively dispense liquids or powders in fixed quantities. Some illustrations of the applications of these systems include:

- In pharmaceutical manufacturing, automated dosing systems are used to accurately dispense active pharmaceutical ingredients and excipients, resulting in a consistent and high-quality final product with lower waste and reduced chances of errors. (Source: Transparency Market Research's "Automated Dosing System Market - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2018 - 2026")
- In food and beverage production, automated dosing systems add exact amounts of ingredients such as colours, flavors, and preservatives, resulting in a consistent and high-quality final product with lower waste and reduced chances of errors. (Source: Mordor Intelligence's "Global Automated Dosing Systems Market for Food & Beverage Industry - Trends and Forecast 2020-2025")
- In water treatment plants, automated dosing systems add precise amounts of chemicals such as chlorine, fluoride, and coagulants to ensure the water is safe to drink and adheres to regulatory standards. (Source: Grand View Research's "Automated Dosing Systems Market Size, Share & Trends Analysis Report By Application (Water Treatment, Food & Beverages, Pharmaceuticals), By Region (North America, Europe, APAC, CSA, MEA), And Segment Forecasts, 2021 - 2028")

Water treatment: In water treatment plants, dosing systems add chemicals such as chlorine, alum, and fluoride to remove impurities and make it safe for consumption. These systems can precisely control the dosing rate and ensure the correct amount of chemicals are added to the water.

Borehole management: Dosing systems can add chemicals or acids to boreholes to dissolve minerals, such as calcium and magnesium, that cause scaling and blockages in the borehole. This can help to maintain the flow rate and prolong the life of the borehole.

Sewer systems: In sewer systems, dosing systems can be used to add chemicals such as disinfectants to prevent the growth of bacteria and reduce odors. They can also be used to add coagulants or flocculants to help settle solids and improve the efficiency of the sewage treatment process.

pH control: Dosing systems can adjust water pH in various applications, such as swimming pools, industrial processes, and agricultural irrigation. This can help prevent corrosion, improve plant growth, and ensure the water is safe.

- In agriculture, automated dosing systems add precise amounts of fertilizers, pesticids, and herbicides to crops, resulting in increased efficiency in farming processes, reduced waste, and minimized chances of over or underusing chemicals. (Source: Mordor Intelligence's "Global Automated Dosing Systems Market in Agriculture - Trends and Forecast 2020-2025")
- In chemical manufacturing, automated dosing systems are used to accurately dispense raw materials and reagents, resulting in a consistent and high-quality final product with lower waste and reduced chances of errors. (Source: MarketsandMarkets' "Automated Dosing System Market - Global Forecast to 2024")

Overall, automated dosing systems offer various advantages regarding precision, efficiency, and safety across multiple industries.

3. Data Collection

The researcher had the opportunity to invest in Primary and Secondary data during this research which includes on site research, as well as revenue from other mines during site visitations, use of articles documenting the uses of lime and best approaches in lime dosing. The collected data will aid in developing the final design that best solves the problems currently brought by the current lime dosing system at the Bulawayo Mining company.

3.1 Primary Research

The researcher was industrially attached to the Gold processing plant for about 6 months. The researcher was exposed to the crushing circuit, milling circuit and the CARBON in Pulp circuit. These circuits enhanced the understanding of why and when lime should be added. During this time the researcher was able to conduct interviews with plant operators who handle the lime, which showed the dangers that lime had added to their wellbeing. The researcher had the opportunity to visit the onsite clinic to see the cases admitted due to excessive intake of the chemical lime.

3.2 Secondary Research

The researcher was exposed to the company archives containing in-depth information on the processes done. The archives also contain the effects of the lime on operators and other relevant information used in this project Generation. The researcher used existing documents, articles, manuals and books of Mines that use lime in their gold processing plants, how they use it and methods of dosing. This assisted as it eye-opened the researcher to different dosing methods and which best to select for the Bulawayo Mining Company.

4. Calculation

Pumps pump water into the dilution tank and the lime solution into the dosing tank. An existing centrifugal pump is used to pump the water. A peristaltic pump is used as the dosing pump for the lime.

Table 2. Pump selection

TYPE	Capability	Speed	reliability	Ease of installation	durability	price	Total
PISTON	3	4	3	5	3	2	20
DIAPHRAGM	5	4	4	4	4	3	24
PERISTALTIC	5	3	5	4	5	4	26

Dosing pump discharge pipe: Using a 25 mm diameter
Effective length = 100m
Static Lift= 10m
Mass balance = $0.35m^3/h$
Pump safety factor = 1.5
Design flow rate = $0.35x1.5=0.53m^3/h$……………………………………………………(2)
$velocity = \frac{4\times0.53}{3600\times\pi\times0.025^2} = 0.29m/s$ ……………………………………………………..(3)
Reynolds Number = $\frac{0.025\times0.29\times1.25\times10^6}{4} = 2265$…………………………………………...(4)
$$\frac{1}{\sqrt{f}} = \left[1.14 + 2\log\left(\frac{D}{\varepsilon}\right)\right] = 0.629 \text{……………………………………….(5)}$$
Roughness of steel=0.045
Relative roughness=$\frac{\varepsilon}{d}=\frac{0.045}{25} = 0.002$……………………………………………………(6)
Friction loss= $f\frac{lv^2}{D2g} = 0.629\left(\frac{100\times0.29^2}{0.025\times2\times9.81}\right) = 10.78$……………………………………...(7)

A **25mm** diameter is chosen for the dosing pipe discharge.
Pipe discharge pressure = 10kPag
Head ratio = 1
Therefore, TDH of water= 11.17m

Pump water curve efficiency =0.8

Pump shaft power= $\frac{flowrate \times TDH \times SG}{3.6 \times EFFICIENCY \times 102} = \frac{0.53 \times 11.17 \times 1.25}{3.6 \times 0.8 \times 102} = 0.025kW$ …………………...(8)

Drive mechanical efficiency = 0.95

Using a VSD derating factor of 0.98

Motor Shaft power = $\frac{Pumpshaft\ power}{derating\ factor \times mechanical\ efficiency} = \frac{0.025}{0.95 \times 0.98} = 0.027kW$ …..…. (9)

Motor safety factor =1.2

Required motor power = 1.2×0.027=0.0324kW

Selected motor power **= 0.37kW, (it is to be directly coupled)**

5. Results And Discussion

The micro controller in this concept is an Arduino. It collaborates with pH sensors and ultrasonic sensors to deliver effective dosing. The ultrasonic sensors use ultrasonic waves to measure the distance. The pH sensor's job is to determine pulp pH. An an automatic dosing system for the lime from the mixing tank, the servo system is present. To maintain pH balance, which should be at 9, the lime solution is pumped into the second tank using a peristaltic pump. If the LED is turned red (as shown in Figure 8), the solution is too acidic; if it is turned yellow, the solution is too basic. The ultrasonic sensor helps maintain the tank's volume of lime solution. The ultrasonic sensor communicates with the microcontroller when the volume exceeds the required amount. Figure 7 shows the prototype.

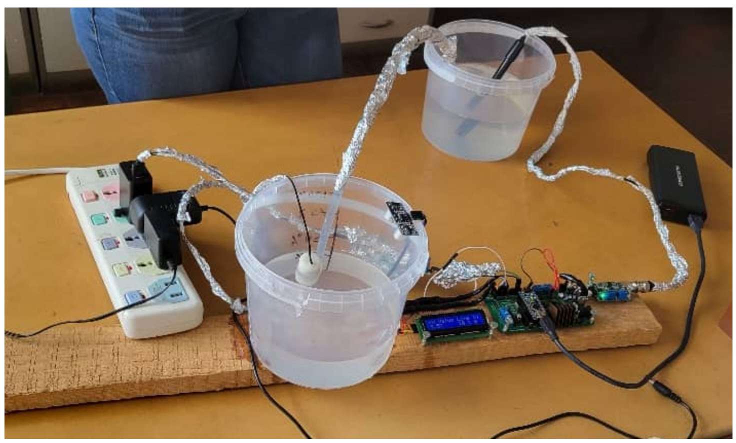

Figure 7. Prototype setup

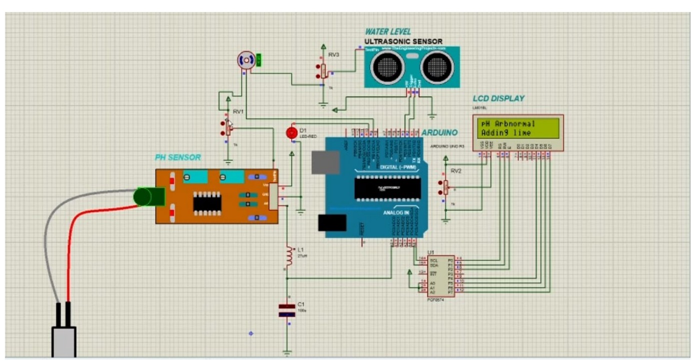

Figure 8. Circuit drawing of the concept

Results from Prototype Tests Done

Scenario 1: pH below 9

When the pH sensor recorded a value of pH less than 8. The pump connected to the circuit using a relay automatically switched on and dosed lime for 8seconds. The LCD displayed a notification "pH Abnormal Adding Lime" as lime was added (as shown in figure 9). Every 8 seconds, the pump would stop pumping to allow the pH meter to capture the value of the newly dosed solution, which would rise with every dose.

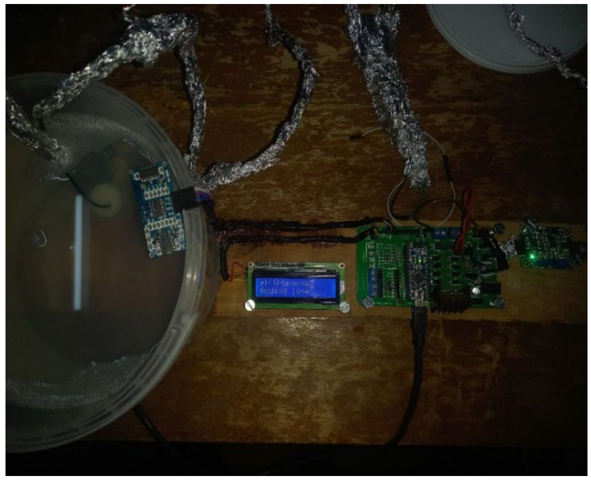

Figure 9. An image showing the LCD Display every 8seconds when pH was less than 9

Scenario 2: pH above 9

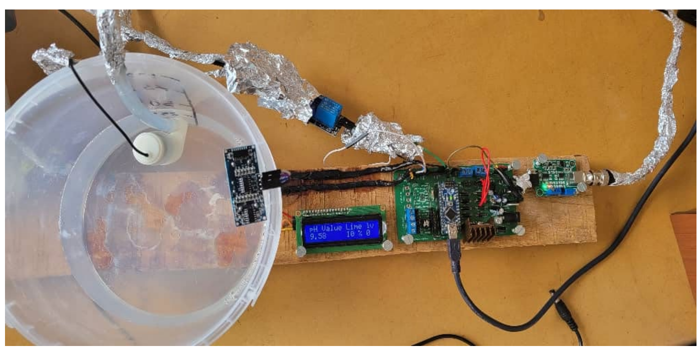

Figure 10. An image showing when the LCD Display was above 9

Once the pH value passed 9 the pump would automatically stopped pumping. The pH was displayed on the LCD as displayed in Figure 10. This meant that the dosing had successfully occurred. The pictorial simulations show us how the different devices act when subjected to various conditions. The simulations showed that, when pH was below 9, a notification was displayed on the LCD SCREEN, to show that lime had to be added. This is also seen in Figure 10, where pH is abnormal thus lime is added using the servo valve. Once the LED is turned off, the lime addition stops, which means the pH has stabilized. The simulation showed that a closed loop system was ideal and thus selected for the control system. The prototype showed different results for the two scenarios. Aluminum foil had to be used minimize the interference in magnetic field between the pump and the pH sensor. The Relay was also used to help with the interferences which proved fruitful. For the industrial setup the PLC is to be the ideal controller. For the prototype the researcher made use of the Aurduino Nano microcontroller

6. Conclusion & Recommendations

This project has accomplished the successful design of an automated lime dosing system, which effectively addresses the challenges faced by the gold processing plant. The system can dose lime accurately and precisely, increasing efficiency and reducing costs. The design looks at the selection of suitable sensors and the development of a userfriendly interface for operators. There is a great potential to integrate the system with other processes in the gold processing plant. Future research could explore using artificial intelligence and machine learning algorithms to enhance the system's performance and lower maintenance requirements. The successful design of an automated lime dosing system has the potential to significantly benefit the gold processing industry, by boosting efficiency, reducing costs and improving safety.

The researcher provided a functional prototype which was the visual for this entire project. The challenges faced were the interference of some components in the magnetic field eventually leading to implementing measures like aluminum foil and relays. The cost aspect of the project meant using affordable components that were not entirely the best but could serve the intended purpose. This study gave insight into the negative impact of the existing lime dosing system of the Bulawayo Mining Company. An automatic dosing system designed in this research is relevant to the current problem. To ensure the reliability and scalability, it is recommended to conduct further tests and optimization before implementation.Operators should have an understanding of the working principle of the dosing mechanism. It is recommended to have training on the general operation of the system. This mechanism can also be applied to other sections of the plant like the flocculent dosing system to avoid problems of inconsistent dosing, operator error, safety concerns, monitoring and control.This system can also be included outside the gold mining setup in other industries like, water treatment plants, borehole management, sewer systems, etc.

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Biography

Zibusiso Jila Dube is a student in the department of Industrial and Mechatronics Engineering at the University of Zimbabwe who has completed her Honours Degree in Mechanical Engineering in 2023.

Loice Gudukeya is a Industrial & Manufacturing Engineer and Renewable Energy Professional. She attained her PhD in Engineering Management at the University of Johannesburg, in 2018, and her Master's Degree in Renewable Energy at the University of Zimbabwe in 2012 and her Honours Degree in Industrial and Manufacturing Engineering at NUST (Bulawayo, Zimbabwe) in 2004. Senior Lecturer and Head of Industrial and Mechatronics Engineering Department at the University of Zimbabwe. She is also a Senior Research Associate in the Faculty of Engineering and the Built Environment at the University of Johannesburg in South Africa. Her research areas are Environmental Sustainability and Cleaner production. She has published a chapter in a book, a number of journal and conference papers, all with reputable publishers.

Abid Yahya is an accomplished professional with a strong educational background and extensive Electrical and Electronic Engineering expertise, specialising in telecommunications. He obtained his Bachelor's degree from the prestigious University of Engineering and Technology in Peshawar, Pakistan. Building upon his foundational knowledge, he pursued advanced studies and earned his MSc and PhD in Wireless and Mobile Systems from Universiti Sains Malaysia. Abid Yahya is a valuable faculty member of the Botswana International University of Science and Technology. His practical knowledge and educational experience make him a sought-after consultant for prominent enterprises. Within his professional journey, Abid Yahya has attained esteemed positions, such as a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) in the United States. Additionally, he holds the title of

Professional Engineer certified by the Botswana Engineers Registration Board (ERB), further exemplifying his commitment to his field. With a prolific academic career, Abid Yahya has significantly contributed to the scholarly community. He has authored over 140 publications in renowned journals, conferences, and books, showcasing his dedication to advancing knowledge in his domain. His remarkable work has garnered recognition through numerous awards and grants from various funding sources, further highlighting his expertise and impact in the field.