

Research Article

Identification and Environmental Consequences of Long-term Stored Chemicals in Ethiopia Pulp and Paper Industry

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Abstract

The study focuses on analysis of long term stored unknown chemicals and environmental impacts of stored chemicals at Ethiopia's Ethiopia Pulp and Paper Factory. In order to guide safe disposal or reuse, the goal is to identify and evaluate the chemical's qualities, especially its acidity, basicity, and composition. Both survey-based and laboratory methodologies are used in the investigation. While physical and chemical studies, such as pH measurements and cationic ion analysis, are carried out, information on chemical storage conditions is gathered using a standardized questionnaire. Soil samples gathered in the vicinity are examined to assess the environmental impact, and chemical samples are evaluated in water to ascertain their pH and solubility. Accuracy is ensured by multiple tests, the results of which are combined into averages and standard deviations. With pH values ranging from roughly 3.63 to 8.63, the results show that the compounds have a spectrum of weak acidic to weak basic characteristics. Aluminum sulfate is the main component found in the analysis, with traces of starch. Despite chemical contact, soil tests around the stored compounds are mainly neutral, indicating little immediate environmental damage. Sample variations indicate weak basicity or acidity, and the insoluble chemical further indicates intricate chemical interactions. The study confirmed that the stored chemical is mainly aluminum sulfate, a weak acid or base, posing limited environmental danger at current concentrations. The findings support safe disposal or potential reuse by industries, emphasizing the importance of proper chemical handling to mitigate ecological risks. Overall, the study provides a basis for informed management of chemical waste in industrial settings, promoting environmental safety and sustainable practices.

Keywords

Aluminum Sulfate, Chemical Storage, Environmental Impact, Sustainable Practices

1. Introduction

As a driver of economic expansion, technological development, and social progression, industrialization is essential to the advancement of civilization [1]. The growth of industries around the world is a prime example of how humans may

use natural resources to meet the rising demand for goods and services. However, when hazardous materials are included, environmental issues frequently accompany this progress. Chemicals must be managed, stored, and disposed of properly

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in order to maintain sustainable industrial practices, safeguard public health, and stop environmental deterioration [2].

Over the past few decades, Ethiopia's industrial sector has grown significantly, especially in the production of pulp and paper. The oldest pulp and paper company in Ethiopia, the Ethiopian Pulp and Paper Share Company, has been in business for more than 60 years. Historically, pulp production and waste paper recycling have been its main priorities in order to produce a variety of paper products, like cartons, Manila paper, and A4 paper. Caustic soda, starch, fillers, and dyes, have been employed by the industry throughout its operational history. These chemicals are essential for guaranteeing both process efficiency and product quality.

However, the long-term storage and management of chemicals, especially in older manufacturing industries, pose significant environmental and safety concerns [3]. During recent site assessments, it was observed that a substantial quantity of unidentified chemicals had been stored outdoors within the factory premises, covering a large land. These chemicals had been stored for over 30 years without proper labeling, documentation, or containment measures, raising critical questions about their composition and potential environmental impacts [4]. The chemical storage area is directly in contact with surrounding soils and vegetation, like local green grasses and agricultural land, which amplifies the risk of soil and water contamination [5].

The ambiguity surrounding the chemical's identity has led to conflicts between the industry and the local community [6]. Residents have expressed concerns over soil degradation, potential health hazards, and the safety of water resources that may be affected by seepage or runoff from the chemical storage sites. The industry, on the other hand, faces difficulties in managing or disposing of the unidentified chemicals due to the lack of factual data leading to environmental and operational challenges [7]. Despite reaching out to local governmental agencies and environmental authorities, no definitive action or guidance has been provided to date. This situation underscores the urgent need for systematic chemical analysis to assess the risks and formulate appropriate mitigation strategies.

The primary challenge in managing this chemical inventory stems from its unknown nature repacked, mixed, and stored for long times in open environments. The absence of labels, records, and expert assessments hampers efforts to evaluate its toxicity, environmental behavior, and safe disposal methods [8]. If unmanaged, these chemicals threaten to cause further soil contamination, water pollution, and adverse health effects for nearby communities, thereby intensifying the socio-environmental conflict.

In light of these conditions, the goal of this study is to close the crucial knowledge gap by carefully examining the chemical compounds kept throughout the industrial grounds. The chemical identification, pH properties, ion composition, and possible toxicity will all be ascertained by laboratory research [9]. Additionally, controlled tests using plant seedlings will be

used to evaluate the effects of these compounds on soil health and plant growth. The results will guide the creation of efficient mitigation techniques, such as strategies for environmental management and safe disposal.

The ultimate goal of this research is to support Ethiopian industrial practices that are sustainable and safe. Policymakers, industrial stakeholders, and local populations can be better prepared to carry out suitable management and cleanup measures by determining the characteristics of the chemical and comprehending its ecological consequences. By ensuring that industrial progress does not come at the expense of environmental stability and public well-being, the effort is in line with more general objectives of environmental conservation, industrial accountability, and community health protection.

Objectives of the Study

- 1) To conduct comprehensive laboratory analyses to identify the chemical compounds stored at the Ethio-pulp Share Company premises.
- 2) To evaluate the pH characteristics and potential toxicity of the identified chemicals.
- 3) To assess the effects of the unidentified chemicals on soil health and plant growth through controlled experiments with plant seedlings.
- 4) To formulate effective mitigation measures for the safe disposal and management of the identified chemicals.
- 5) To involve local communities and stakeholders in the research process, ensuring their concerns and insights are considered in the findings and recommendations.

2. Materials and Methods

2.1. pH Determination of Stored Chemical Samples and Surrounding Soil

To investigate the acidity and basicity of the stored chemical substances, a systematic laboratory analysis was conducted utilizing a calibrated pH meter. Given the limited sample size of the stored chemicals, the entire available quantity was used for the analysis, and the sampling approach was non-systematic due to the small volume. A total of 26 chemical samples were obtained by extracting 20 grams from each of the chemical packs [10]. Additionally, three soil samples were collected from the vicinity of the chemical storage site to assess potential environmental interactions.

Post-collection, each chemical and soil sample was labeled sequentially as Sample 1 through Sample 26, and the soil samples as Soil Sample 1, 2, and 3, respectively. To determine the solubility profile, all samples were tested for water solubility by dissolving a small quantity in distilled water and observing the mixture [11]. The samples demonstrated water solubility, indicating their likely inorganic nature or the presence of hydrophilic functional groups.

Subsequently, pH measurements were performed on each

sample using a portable pH meter. The device was calibrated prior to measurements to ensure accuracy. For each sample, the solution was stirred gently to ensure homogeneity before immersing the calibrated electrode. The pH was recorded once a stable reading was achieved. The collected data were then documented systematically for further analysis. This methodology provided insights into the chemical properties of the stored substances and their potential environmental impacts based on acidity or alkalinity.

2.2. Anionic and Cationic Determination

The determination of cations and anions within the chemical samples was conducted through qualitative inorganic analysis, utilizing standard reagent tests and observation of precipitate formation [12]. For cationic analysis, approximately 20 g of each chemical sample was dissolved in distilled water to produce a clear, colorless solution, which was then filtered to remove insoluble impurities [13]. The filtrate served as the test solution for cation identification. A series of reagent tests were performed systematically: hydrochloric acid (HCl) was added to detect the presence of heavy metals such as silver (Ag^+), lead (Pb^{2+}), and mercury (Hg^{2+}), with the absence of white precipitates indicating their likely absence. Hydrogen sulfide (H_2S) in acidic media was employed to identify metal sulfides, which appear as characteristic precipitates. The addition of carbonate buffers was used to detect carbonate ions (CO_3^{2-}), while barium chloride (BaCl_2) solution was introduced to confirm sulfate ions (SO_4^{2-}) through the formation of a white barium sulfate precipitate. The presence or absence of specific precipitates, along with their solubility properties, enabled the qualitative identification of the cations involved [13].

For anionic analysis, the same prepared solutions were subjected to tests for sulfate and carbonate ions. Acidic addition of dilute hydrochloric acid (HCl) facilitated the detection of carbonate ions, evidenced by effervescence due to carbon dioxide gas evolution. To confirm sulfate ions, barium chloride solution was added, which resulted in the formation of a characteristic white precipitate of barium sulfate. The observed reactions precipitate formation or gas evolution provided qualitative evidence of the specific anions present in the samples.

2.3. Impact of Stored Chemicals on Plant Growth and Seedling Development

The purpose of this research is to study the gradual effect of chemicals stored in the environment on plant growth by ob-

serving the development of seedlings. This is accomplished by preparing soil samples and applying chemical solutions at various concentrations, such as 10 g, 20 g, 50 g, and 100 g, dissolved in water. Experimental pots are filled with approximately 1 kg of soil, with different chemical concentrations added to each, including a control sample with water only. Healthy seeds, such as corn, are then planted in each pot, and the respective chemical solutions are thoroughly mixed into the soil to ensure even distribution. The pots are maintained under controlled environmental conditions with adequate sunlight, temperature, and consistent watering to facilitate seed germination and seedling growth over a period of more than four months [14]. Regular observations are made to record germination rates, seedling height, leaf development, and overall health, with photographic documentation at consistent intervals. The collected data are analyzed to evaluate the impact of different chemical concentrations on seedling development, identify signs of toxicity, and assess environmental risks associated with chemical storage and disposal practices [15]. This approach aims to provide insights into how stored chemicals, particularly aluminum sulfate and related compounds, may affect plant growth and the surrounding ecosystem, thereby informing safe management and disposal strategies.

2.4. Effects of Chemical Treatment on Soil and Seedling Growth

In this study, six identical pots were prepared, each containing 1 kg of the same soil type, to investigate the effects of varying chemical treatments on soil and seedling growth. Each pot received specific amounts of a chemical, either 10 g, 20 g, 50 g, or 100 g, which were dissolved in water before application. In the first pot, 50 g of the chemical was added to the 1 kg of soil, followed by water to ensure proper dissolution. The second pot also contained 1 kg of soil with 50 g of chemical, but in this case, water was added along with a seedling to assess growth potential. The third pot received a more substantial treatment of 100 g of chemical, followed by water and the placement of a seedling. In the fourth pot, 20 g of chemical was introduced to the 1 kg of soil, along with water and a seedling. The fifth pot contained 10 g of the chemical with water and a seedling. Finally, the sixth pot, which also included 1 kg of soil and 50 g of chemical, differed by incorporating a different seedling type alongside water to analyze its response to the chemical treatment. This systematic approach allows for a comprehensive evaluation of the effects of chemical amendments on soil properties and plant growth outcomes.

3. Results and Discussion

3.1. pH Determination of Stored Chemical Samples and Surrounding Soil

Table 1. pH Values of Chemical and Soil Samples.

No of samples	Test numbers	Results of Tests	Average	Remark
Sample 1	Test 1	7.78	7.883 ±0.092915732	Weak base
	Test 2	7.96		
	Test 3	7.91		
Sample 2	Test 1	3.76	3.6266 ±0.105830052	Weak acid
	Test 2	3.54		
	Test 3	3.58		
Sample 3	Test 1	3.94	4.1133 ±0.158219257	Weak acid
	Test 2	4.25		
	Test 3	4.15		
Sample 4	Test 1	7.93	8.6333 ±0.618088451	Weak base
	Test 2	9.09		
	Test 3	8.88		
Sample 5	Test 1	4.69	4.646 ±0.083864971	Weak acid
	Test 2	4.70		
	Test 3	4.55		
Sample 6	Test 1	5.12	5.1866 ±0.065064071	Weak acid
	Test 2	5.19		
	Test 3	5.25		
Sample 7	Test 1	5.02	4.963 ±0.049328829	Weak acid
	Test 2	4.93		
	Test 3	4.94		
Sample 8	Test 1	6.34	6.496 ±0.146401275	Weak acid
	Test 2	6.63		
	Test 3	6.52		
Sample 9	Test 1	6.20	6.173 ±0.030550505	Weak acid
	Test 2	6.14		
	Test 3	6.18		
Sample 10	Test 1	5.19	5.21 ±0.068068593	Weak acid
	Test 2	5.29		
	Test 3	5.16		
Sample 11	Test 1	4.54	4.39 ±0.13453624	Weak acid
	Test 2	4.35		
	Test 3	4.28		

No of samples	Test numbers	Results of Tests	Average	Remark
Sample 12	Test 1	5.17	5.456 ±0.295352896	Weak acid
	Test 2	5.76		
	Test 3	5.44		
Sample 13	Test 1	5.16	5.226 ±0.058594653	Weak acid
	Test 2	5.25		
	Test 3	5.27		
Sample 14	Test 1	5.81	6.013 ±0.176729549	Weak acid
	Test 2	6.13		
	Test 3	6.10		
Sample 15	Test 1	6.36	6.42 ±0.065574385	Weak acid
	Test 2	6.49		
	Test 3	6.41		
Sample 16	Test 1	5.96	6.00 ±0.036055513	Weak acid
	Test 2	6.03		
	Test 3	6.01		
Sample 17	Test 1	6.53	6.62 ±0.08326664	Weak acid
	Test 2	6.65		
	Test 3	6.69		
Sample 18	Test 1	6.92	7.12 ±0.205182845	Weak base
	Test 2	7.11		
	Test 3	7.33		
Sample 19	Test 1	7.17	7.126 ±0.045092498	Weak base
	Test 2	7.08		
	Test 3	7.12		
Sample 20	Test 1	It is insoluble chemical	Is not additive and not soluble	
	Test 2			
	Test 3			
Sample 21	Test 1	5.76	5.493 ±0.231804515	Weak acid
	Test 2	5.34		
	Test 3	5.38		
Sample 22	Test 1	5.53	5.53 ±0.02	Weak acid
	Test 2	5.55		
	Test 3	5.51		
Sample 23	Test 1	4.20	4.00 ±0.176162803	Weak acid
	Test 2	3.95		
	Test 3	3.86		
Sample 24	Test 1	6.32	6.89 ±0.397030645	Weak acid
	Test 2	6.97		
	Test 3	7.04		

No of samples	Test numbers	Results of Tests	Average	Remark
Sample 25	Test 1	7.37	7.36 ±0.105356538	Weak base
	Test 2	7.25		
	Test 3	7.46		
Sample 26	Test 1	7.07	7.066 ±0.015275252	Weak base
	Test 2	7.05		
	Test 3	7.08		
Soil Sample 1	Test 1	7.08	7.08 ±0.01	Weak base
	Test 2	7.07		
	Test 3	7.09		
Soil Sample 2	Test 1	7.03	7.026 ±0.025166115	Weak base
	Test 2	7.05		
	Test 3	7.00		
Soil Sample 3	Test 1	6.97	6.96 ±0.01	Weak acid
	Test 2	6.96		
	Test 3	6.95		

The Table 1 presents the results of pH measurements conducted on various chemical and soil samples to determine their acidity or basicity and assess their potential environmental impact. A total of 26 chemical samples and 3 soil samples were analyzed through three trials each to ensure accuracy and repeatability.

The chemical samples exhibited a broad range of pH values from strongly acidic to weakly basic, classified into weak acids, weak bases, and an insoluble chemical [16]. Specifically, samples such as Sample 2 (pH ≈ 3.63) and Sample 3 (pH ≈ 4.11) demonstrated weak acidity, indicative of the presence of acidic compounds like aluminum sulfate. Conversely, samples such as Sample 1 (pH ≈ 7.88) and Sample 26 (pH ≈ 7.07) displayed weak basic properties, suggesting the presence of basic compounds or impurities.

Particularly, some samples showed variability across trials, but calculated averages with standard deviations provided a reliable estimate of their typical pH. For example, Sample 17 had an average pH of 6.62 ± 0.083 , indicating a weak acid, whereas Sample 18 recorded an average of 7.12 ± 0.205 , indicating a weak base. An exception was Sample 20, which was identified as insoluble and was not suitable for pH measurement, highlighting the chemical's insolubility and potential distinct impact on the environment.

The soil samples consistently demonstrated neutral to slightly acidic or basic pH values, with Soil Sample 1 neutral (pH ≈ 7.08), Soil Sample 2 slightly alkaline (pH ≈ 7.03), and Soil Sample 3 slightly acidic (pH ≈ 6.97). These findings suggest that despite the presence of stored chemicals, the surrounding soil maintains near-neutral pH, indicating min-

imal immediate impact on soil acidity or alkalinity [17].

3.2. Anionic and Cationic Determination

The scheme is prepared based on analytical techniques. Cationic analysis carried-out based on the reagents HCl, H₂S, CO₃²⁻, SO₄²⁻. These anions are important reagents to determine the presence of group; I, II, III, IV and V cations based on their degree of solubility [12].

From Figure 1, the first step was identification of heavy metals- for this analysis hydrochloric acid (6M) was used. Here the chemical samples collected are solid rocky and soluble in water. This implies that the probability of being organic is less and hence the samples are under the category of inorganic compounds. Therefore, for further confirmation of being inorganic is to carry out cationic analysis. The major expected cations are alkaline earth metal, or aluminum and its family. Not all 26 chemical samples have been analyzed for cation analysis but only sample whose pH=3.66 and 8.9 were selected. These two samples were then dissolved in water and filtered with filter paper to obtain transparent colorless solution. After the solution of the two was prepared, HCl was added to observe the formation of white precipitate followed by centrifugation. Then 6M of HCl solution was added to the solution of chemical sample whose pH=3.66 and 8.9; unfortunately, there was no white precipitate or no milky cloudy was formed. This most probably indicated that chemical samples didn't contain any of the heavy metals such as Ag⁺, Pb²⁺, Hg²⁺ [18].

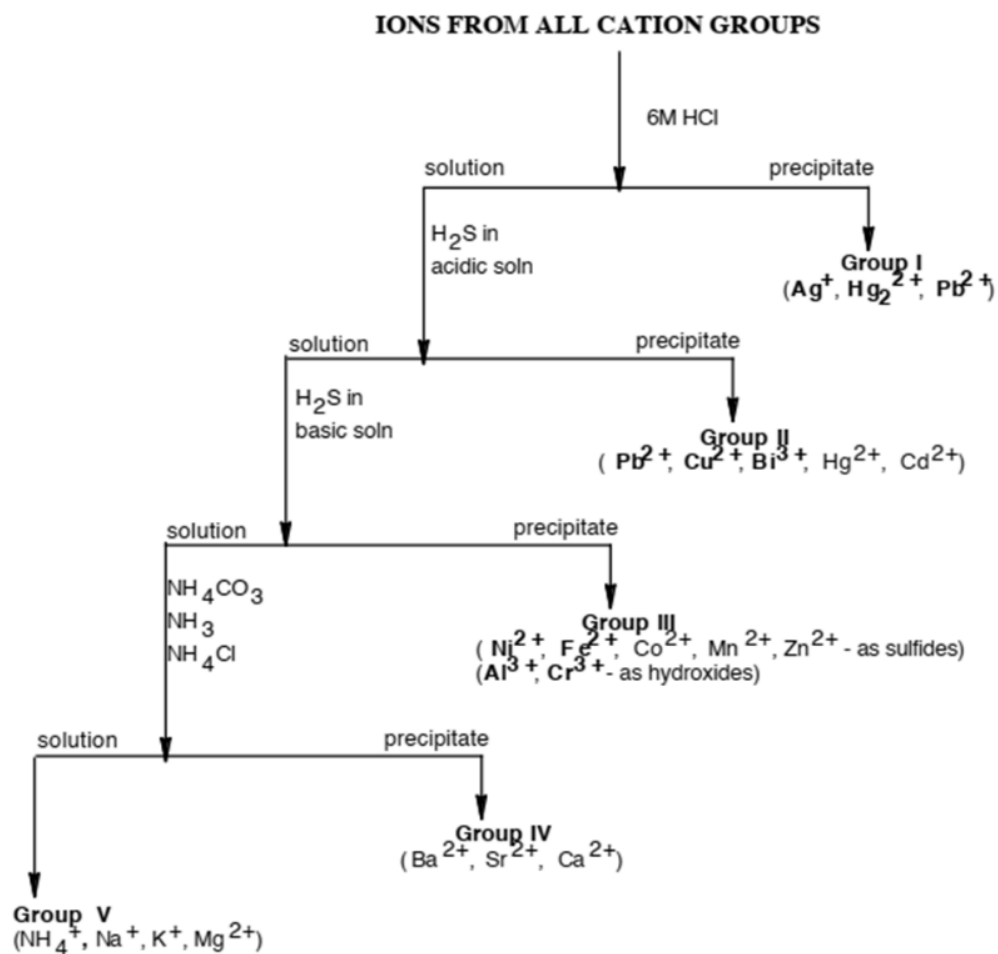


Figure 1. Cationic and Anionic Determination Procedure.

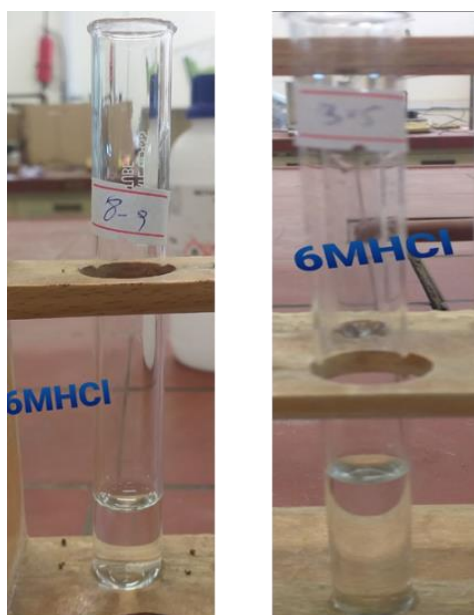


Figure 2. After Addition of 6M HCl on Samples with pH=3.66 and 8.66.

Cationic Analysis using H_2S

The chemical sample whose pH=3.66 and 8.9 were dis-

solved in water and then followed by filtration. The colorless solution of both sample were mixed with H_2S solution in

acidic media. After the addition of the acidic solution white milky cloud was observed as shown in Figure 2 and it indicates the presence of one of the expected cations. To further confirm which cation is probably present in the sample we

have further investigated in basic media by mixing the chemical sample whose pH= 3.66 with NaOH and thus white milky cloud was appeared in the solution which is the indication of the presence of Al^{3+} as shown in Figure 3.

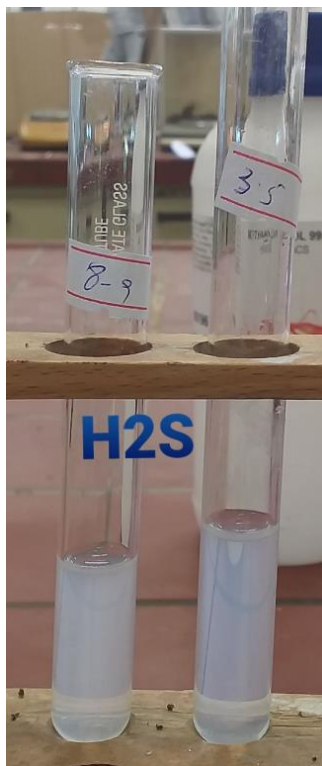


Figure 3. Formation of Milky cloud Suspension After Addition of H_2S in Acidic Media.

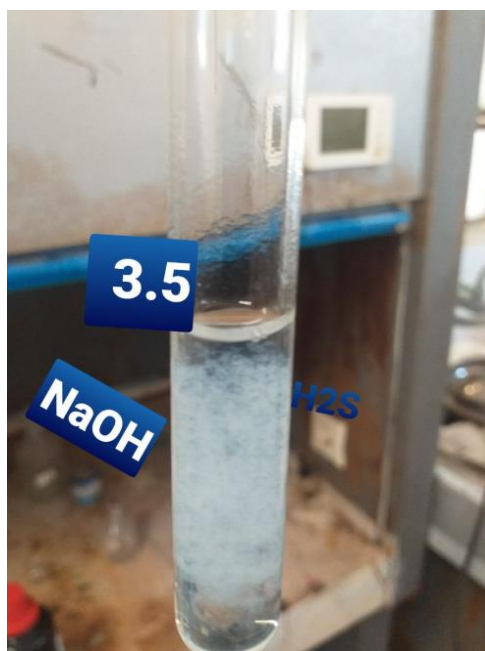


Figure 4. Formation of Milky Cloud Suspension After Addition of NaOH in Basic Media.

Further investigation was carried out by preparing the solution of chemical samples in water. The chemical sample

solution was then mixed with Na_2CO_3 and $(\text{NH}_4)_2\text{CO}_3$. After the addition there was no precipitate is formed only clear

solution was appeared. This implies that there is no group II cations found in the sample [Figure 4](#).



Figure 5. No White Precipitate Was Formed When Na_2CO_3 and $(\text{NH}_4)_2\text{CO}_3$.

For further confirmation the experiment was carried out by changing the reagents and add into chemical samples with different pH= 3.66 and 8.9. In both cases no white precipitate

was formed which is the indication of no group II cations present at all. [Figure 5](#).



Figure 6. No White Precipitate Was Formed When Na_2CO_3 and $(\text{NH}_4)_2\text{CO}_3$.

3.3. Impact of Stored Chemicals on Plant Growth and Seedling Development in Varying Concentrations of Chemical Solutions



Figure 7. Seedlings Grow in the Mixture of Soil and Chemical.

The experiment demonstrated that varying chemical treatments significantly impacted soil pH levels, thereby influencing seedling growth [19]. In pots treated with higher chemical doses, such as the third pot with 100 g, the pH dropped drastically to 4.07, posing severe risks to seedling health and potentially stunting growth. Meanwhile, both pots one and two, which received 50 g of chemical, displayed similar trends of increased acidity, with pH levels falling to 4.55 and 4.67, respectively. In contrast, the fourth pot with 20 g of chemical exhibited a more moderate reduction in pH to 5.94, suggesting that lower concentrations may be less harmful and could support healthier seedling growth. The fifth pot, treated with only 10 g of chemical, experienced the least change in pH, thereby creating a more favorable environment for development. The sixth pot, which used 50 g of chemical but involved a different seedling type, indicated that plant responses can vary under identical chemical conditions.

These findings focus the necessity of considering chemical concentrations and their effects on soil acidity, which are critical for optimizing both soil quality and seedling performance in future agricultural practices [13].

3.4. Comparison of Seedling Placed in pH 3.66 and 8.9

In Table 2, which records the pH levels for soil samples with a starting pH of 3.66, the measurements remain consistently acidic across the study period. For instance, Sample 1, which consists of 1 kg of soil with 50 g of chemical and water, maintains a pH of 6.35 throughout the seven weeks, indicating a shift towards less acidity but remaining below neutral (pH 7). Other samples exhibit similar patterns, with the pH values ranging from 4.67 to 6.35, confirming the predominance of acidic conditions in the soil over time.

Table 2. pH Data After Seedling Placed in the Soil and Chemicals of pH 3.66.

S. N	Sample test	PH							Remark
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	
1	1 kg of soil, 50 gram of chemical and water	6.35	6.35	6.35	6.35	6.35	6.35	6.35	Acid
2	1 kg of soil, 50 gram of chemical, seedling and water	4.55	4.55	4.55	4.55	4.55	4.55	4.55	Acid
3	1 kg of soil, 50 gram of chemical, with different seedling and water	4.67	4.67	4.67	4.67	4.67	4.67	4.67	Acid
4	1 kg of soil, 10 gram of chemical, seedling and water	5.94	5.94	5.94	5.94	5.94	5.94	5.94	Acid
5	1 kg of soil, 20 gram of chemical, seedling and water	5.30	5.30	5.30	5.30	5.30	5.30	5.30	Acid
6	1 kg of soil, 100 gram of chemical, seedling and water	3.76	3.76	3.76	3.76	3.76	3.76	3.76	Acid

Table 3. pH Data After Seedling Placed in the Soil and Chemicals of $P^H=8.9$.

S. N	Sample test	PH							Remark
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	
1	1 kg of soil, 5 gram of chemical and water	8.59	8.59	8.59	8.59	8.59	8.59	8.59	Weak base
2	1 kg of soil, 10 gram of chemical, seedling and water	8.19	8.19	8.19	8.19	8.19	8.19	8.19	Weak base
3	1 kg of soil, 20 gram of chemical, different seedling and water	7.4	7.4	7.4	7.4	7.4	7.4	7.4	Weak base
4	1 kg of soil, 25 gram of chemical, seedling and water	7.27	7.27	7.27	7.27	7.27	7.27	7.27	Weak base

S. N	Sample test	PH							Remark
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Weak Basic
5	1 kg of soil, 50 gram of chemical, seedling and water	7.57	7.57	7.57	7.57	7.57	7.57	7.57	Weak base

Conversely, Table 3 illustrates the pH levels for soil samples with an initial pH of 8.9, indicating basic conditions. Measurements for Sample 1, consisting of 1 kg of soil with 50 g of chemical and water, show stability, remaining at 8.59 through Weeks 1 to 3 but slightly decreasing to 8.19 by Week 7. The other samples, such as those with varying amounts of chemical and water, generally maintain a pH range from 7.27 to 8.19, clearly reflecting a basic condition throughout the observation period.

Generally, the findings from these tables stress a significant distinction between the pH behavior of acidic versus basic soil samples in response to the application of chemicals and water. The acidic soils in Table 2 demonstrate gradual increases in pH but do not reach neutrality, while the basic soils in Table 3 maintain their alkaline characteristics within a relatively stable range.



Figure 8. Seedlings of Corn Grown from Seed in Different Chemical Concentration.

Further justification of the toxicity of the chemical was tested with corn seed. According to Figure 8 the corn seed grown in different concentration of chemicals for over 4 months is shown. The seedlings were grown similarly although the concentration was different. Furthermore, the corn seed was placed in the mixture of chemicals and soil.

4. Conclusions

The comprehensive investigation of the stored chemical

sample at Ethiopia pulp and paper S.Co shown that it predominantly comprises aluminum sulfate, characterized as a mixture of weak acids and weak bases, with trace impurities of organic resins contributing to its basicity. The pH range of 26 samples, spanning from 3 to 9, indicates the presence of both acidic and basic compounds within the chemical, while analysis of three soil samples in contact with the chemical environment showed neutral pH values. This neutrality suggests that acidic chemicals have interacted with the soil, effectively neutralizing their acidity.

Environmental impact assessments further demonstrated that seedlings of various species, grown in soil supplemented with different concentrations of the chemical (ranging from 5 g to 100 g per kilogram of soil), exhibited no adverse effects or growth abnormalities over more than four months. The seedlings' unaffected growth across diverse chemical concentrations and species underscores the chemical's low toxicity and environmental stability, implying minimal risk to surrounding flora during such exposure.

Generally, these findings suggest that the chemical, mainly aluminum sulfate, poses limited environmental hazards under current storage and exposure conditions. Its weak acidic and basic properties, coupled with demonstrated biological safety over the tested period, support the potential for safe disposal or reuse within industry processes. However, continuous monitoring and proper management practices are recommended to prevent long-term environmental impacts, ensuring sustainable handling of stored chemicals in industrial settings.

5. Recommendation

The Ethiopian Pulp and Paper Factory must establish and adhere to systematic chemical management practices. This includes labeling, documentation, and regular audits of stored chemicals to prevent mismanagement and ensure safe handling.

The company must implement continuous environmental monitoring around the chemical storage sites. This includes assessing soil and water quality to detect any potential contamination and ensuring that any changes in pH or chemical composition are addressed promptly.

Industries must develop safe disposal methods or recycling processes for the identified chemicals, particularly aluminum sulfate. Utilizing these chemicals in other industrial applications, where feasible, minimizes waste and promotes sus-

tainable practices.

The company must engage local communities in the study of chemical impacts to encourage transparency and build trust. Educational programs must be organized to inform residents about the safety measures taken and the findings of the chemical analyses to alleviate concerns regarding health and environmental risks.

The findings indicate that the predominant composition of the waste is aluminum sulfate, which is not considered hazardous. Therefore, the Environmental Protection Agency (EPA) must implement strategies for effective management and mitigation of these chemicals to ensure environmental safety.

Abbreviations

EPA	Environmental Protection Agency
HCl	Hydrochloric Acid
H ₂ S	Hydrogen Sulfide
NaOH	Sodium Hydroxide
S.co	Share Company

Author Contributions

Sisay Demisse Geda: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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