

---

**INFLUENCE OF pH IN ELECTROKINETIC TREATMENT OF COMPOST**

---

**Anil Kurmana**Department of Environmental Science, GITAM Institute of Science, GITAM Deemed to be University),  
Visakhapatnam-530045 (Andhra Pradesh), India**ABSTRACT**

*It is estimated that about 65 million tons of waste is generated annually in India, out of which about 62 million tons is Municipal Solid Waste (MSW). Only about 75-80% of the municipal waste gets collected and out of this only 22- 28% is processed and treated and remaining is deposited indiscriminately at dump yards. Hyderabad city generates around 5500MT of waste every day. And only 20% of the waste is used for composting using windrow composting process. Municipal Solid Waste composting is a rapid growing method of solid waste management in Hyderabad and In-Vessel composting is the recent initiative by the Govt. to reduce the Organic Solid Waste generated at the source. As per the Solid Waste Management Rules, 2016, all establishments generating bulk garbage of 100 kg and above every day have to install composting machines on their premises to process the waste. Though there is significant demand for quality compost, presence of trace metals has raised question on its application to agriculture practice. Various remediation technologies have been used to treat the soils contaminated with trace elements. Remediation is also essential for compost which may contain contaminants before applying it as a soil amendment. One such technique which was applied for this study is Electrokinetic remediation. This study was conducted to assess the influence of pH in electrokinetic treatment of compost from Municipal solid waste and Vessel composter. At the end of the experiment, it was found that pH has decreased and created an Acidic front at the Anode end. Accumulation of Metal like Chromium, Copper, Nickel, Lead and Zinc have substantially increased during the course of this experiment at the acidic front.*

**INTRODUCTION**

One of the most concerning global issues is Waste, which poses a threat to environment and health. According to world bank reports annually 7-9 billion tons of waste is generated globally, and municipal solid waste (MSW) constitutes around 2.01 billion tons, and this is expected to grow to 3.4 tons by 2050. In this context, the resolution adopted in United Nations (UN) assembly on September 25, 2015, by the name "Transforming our world: the 2030 Agenda for Sustainable Development", is remarkable. It has resolved to take an audacious and transformative path to change the world in a sustainable and sturdy way. 17 interlinked Sustainable Development Goals (SDGs) were set to achieve this. Goal 12 talks about "To ensure Responsible Consumption and Production patterns" with 11 targets, one among them is Target 12.5 ", It says that substantially, reduce waste generation through prevention, reduction, recycling and reuse" to be achieved by 2030 (UN, 2015).

MSW constitutes Organic fraction (biodegradable), Inorganic fraction (Dry Waste including recyclable), Inert (including Construction & Demolition fraction) waste. The Organic fraction of waste contributes to the largest share of MSW. If the waste is properly used it can be a source of nutrient to soil. There are varied forms of waste management options available for waste treatment to recover materials or generate energy from waste which can be classified into three main categories based on their technology and treatment. Mechanical Heat Treatment (MHT), Advanced Thermal Treatment (ATT), Mechanical and Biological Treatment (MBT). MBT systems can be described as two simple concepts: either to separate the waste and then treat; or to treat the waste and then separate (DEFRA,2013). Although with many technologies in place for waste treatment, landfills are the most used of all the technologies. Owing to cost factors and more minor adaptation of newer technologies, landfills top the chart in waste treatment methods. Composting is a suitable technology with various advantages over other waste management techniques. Technology with a low operational cost is advantageous to the environment with low pollution while operating and production of biofertilizers, which is also a source of income. Apart from waste management, compost also plays a crucial role as an amendment in the bioremediation of contaminated soils. Though there are many composting technologies like windrow, aerated static pile, In-Vessel and Vermi-composting, windrow composting is done on a large scale. This is the most common practice used in converting large volumes of waste. Large parts organic portion of MSW is treated using this method, which generates larger quantities of compost. The other alternative method that has been employed recently for conversion of the organic portion of kitchen or food was in-vessel composting. Where organic waste is processed in a closed container or vessel in which airflow and temperature can be controlled, using the principle of the bioreactor. Though compost can be used as organic manure, there are limitations, including detection of the pathogen, low nutrient availability, and detection of trace metals due to cross-contamination from mixed waste. Metals are essential to living form to maintain a healthy life, but when the concentration increase in nature, the tolerable levels become toxic (Elicker et al., 2014). This would

ultimately reach the human population through bioaccumulation when the compost is applied as an amendment to the soil. When human health or ecology is at risk due to contamination, it is believed remediation is necessary. A remediation is an act by which contamination is reduced, isolated, or removed from the environment with a motive to prevent contact with people and animals. Remediation can be done by Biological, Physical, Chemical means, which can further be classified into six techniques, including electro-kinetic extraction, thermal desorption, soil washing, chemical stabilization, phytoremediation, and microbial technology. Remediation is essential for removing the contaminants and restoring the compost to a clean and safe condition. One such technique which was applied for this study is Electrokinetic remediation and the role of pH in the treatment process.

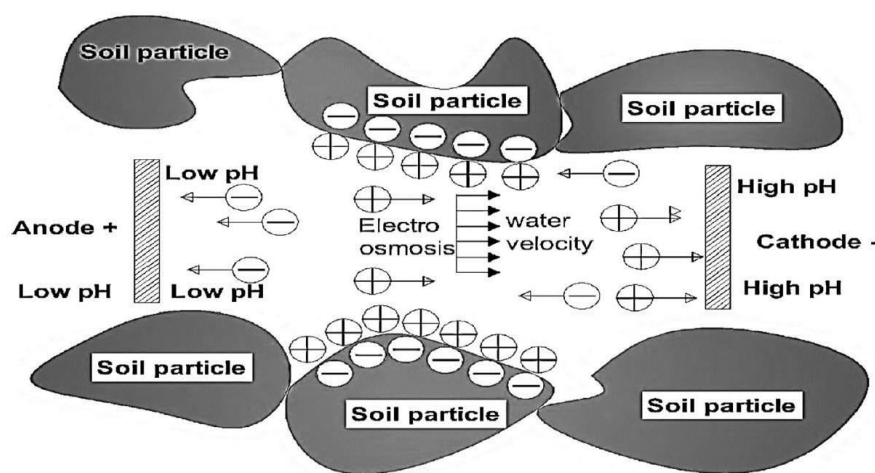
### Electrokinetic Remediation

Electrokinetic remediation is a process by which low voltage direct current is induced to the earth material matrix through electrodes is called Electrokinetic remediation. Due to the electric field that is generated, heavy metal contaminants may be mobilized and concentrated at the electrodes (Anode & Cathode). Electrokinetic remediation uses the three principles of electromigration, electroosmosis, and electrophoresis, Fig 1 presents the electrokinetic process.

**Electromigration** is the movement of ionic species in the electric field towards the electrode of opposite charges in an aqueous medium (Yuchen, 2021). The positively charged cations would move towards the Cathode, and the negatively charged anions towards Anode.

**Electroosmosis** is the net flux of water and dissolved constituents induced by the electric field through the porous structure of the soil. As the flow of current is towards the negative cathode from Anode, the pore fluid moves towards the cathode. The ionic movement of anions is towards the cathode and the cations to cathode. Due to more generation of more cation in the electrolyte the moment of the ions is more towards cathode (Yeung, 1994).

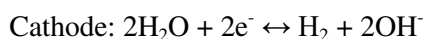
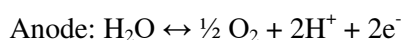
**Electrophoresis** is the transport of charged particles of colloidal size like soil organic matter (SOM), tiny particles of soil. Metals adsorbed to these charged particles move together. However, the migration of colloidal is very negligible due to slow mobility (Han et al., 2021). Tamping of metals with soil/sediment may restrict the movement of colloidal particles; hence, electrophoresis contribution in EK remediation is very limited when compared to electromigration and electroosmosis (Reddy & Saichek, 2003)



**Figure 1: Electrokinetic Remediation Process**

### Basic Principle

When water is used as an electrolyte, the electrodes experience a chemical reaction brought on by the electric field. The water surrounding the electrodes hydrolyses under the influence of the electric field to produce



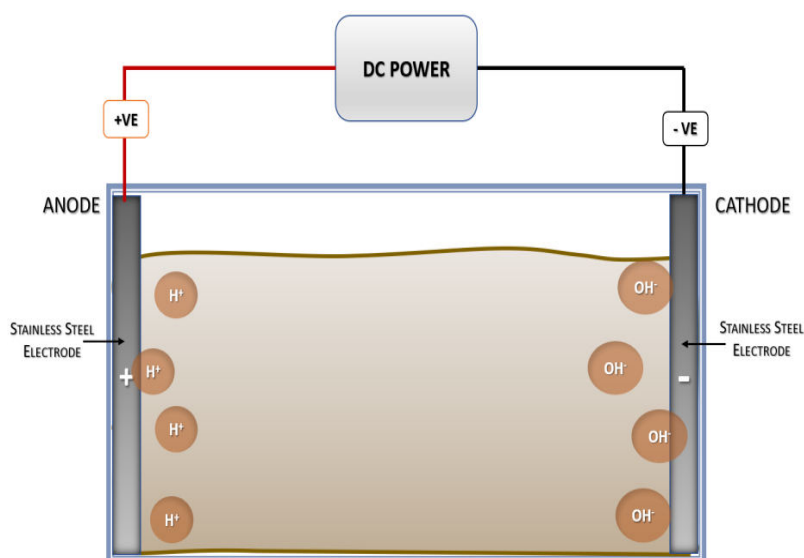
Water loses an electron and forms  $\text{O}^2$  and  $\text{H}^+$ , which decreases the pH concentration at Anode. This would help the metal in soil/sediments to dissolve in the pore water for easy movement of heavy metals. When the excess number of  $\text{H}^+$  are released, this might lead to a directional change in the electro-osmosis flow. (Yuchen, 2021).  $\text{H}_2$  and  $\text{OH}^-$  are produced due to reduction reaction at the cathode; the movement of heavy metals sometimes get hindered due to precipitation with  $\text{OH}^-$  ions.

## MATERIALS & METHODS

For the purpose of this study, compost samples from two different sources in the city of Hyderabad are identified. To assess the influence of pH in electrokinetic treatment of compost samples, compost having raw material from distinct source is chosen. Compost derived from windrow composting of Municipal solid waste, where the raw material is mixed waste is taken as Sample 01. And Sample 2 is compost derived from Vessel composter, where the raw material is organic waste kitchen waste.

### Experimental Setup

A rectangular glass reactor is used as an apparatus to hold the specimen. 10 kgs of compost sample was taken and mixed with 10 litres of water in 1:1 ratio. The sample is thoroughly mixed before incorporating the stainless-steel electrodes into the setup. For Anode and cathode electrode made of stainless-steel is used. A regulated power supply was introduced to the steel plate electrode at Anode and Cathode. Voltage (potential difference) is maintained at 10V throughout the experiment period.



**Figure 2:** Electrokinetic experiment setup

Total of two sets of experimental setups were made, one for **MSW compost** and other for **Vessel compost** samples. Each set consist of experimental setup with treated and untreated samples. For treated samples regulated direct current is introduced to initiate the electrokinetic treatment. The experiment program lasted for 11 continuous days with 8 hours of electrokinetic treatment runtime on each day for treated samples. Experiment samples were collected every alternate day on Days 01, 03, 05, 07, 09 and 11 from both sets. And the compost samples were analysed for physicochemical parameters. A major part of this study is to analyze the presence of heavy metal composition on the treated compost samples. Samples are first sun-dried, followed by drying them in hot air oven at 110° C. The samples are then grinded using mortar and pestle homogeneously to avoid any oversized particles.

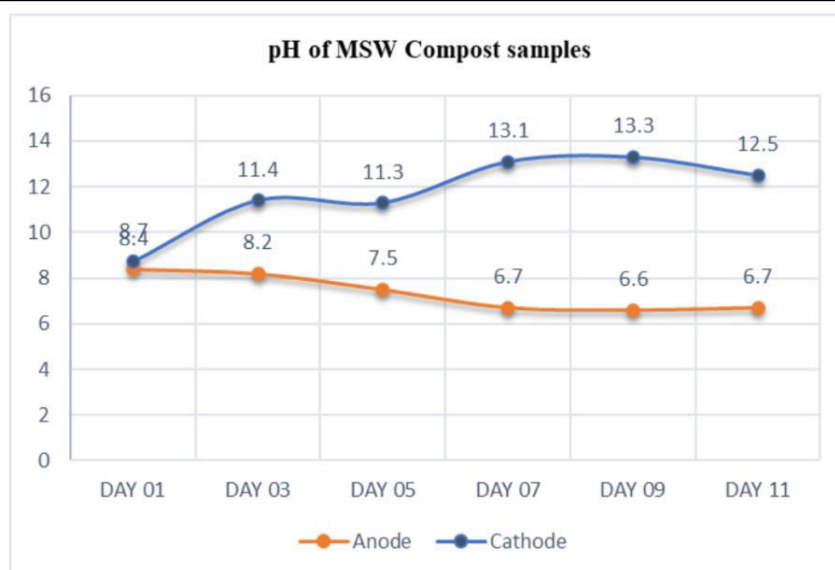
### Physico-Chemical Analysis

Physico-chemical parameters such as pH was done by mixing treated compost sample with deionised water at a ratio of 1 part of compost to 5 parts of deionised water. The mixture is thoroughly missed and left for 1 hour before measuring it for pH. For Trace metals, samples are subjected to acid digestion as per EPA method 3050B. The digested are then analysed using High-resolution Inductive coupled plasma mass spectrometry (HR-ICPMS).

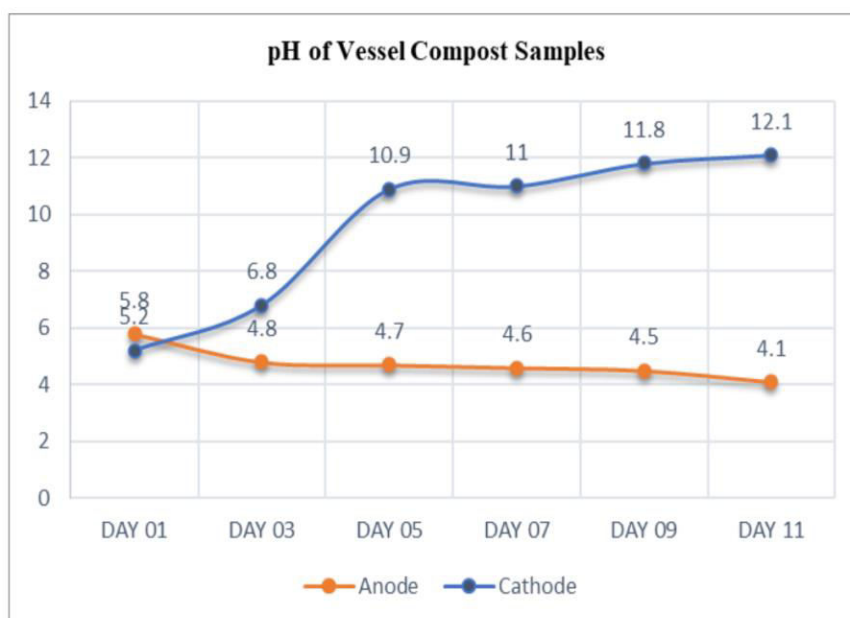
## RESULTS AND DISCUSSIONS

**Variation in Ph with Time** pH is a measure of hydrogen ions concentration in a solution. If the amount of hydrogen ions increases in the sample, the pH decreases and vice versa. In our samples' measured pH has varied from the control samples to that of the samples collected at Anode to Cathode on day 1 to day 11. The pH of the control sample or untreated sample was 8 for MSW compost and 7 Vessel Compost.

It is observed that the pH in MSW compost samples has decreased from 8.4 to 6.6 at Anode and increased from 8.7 to 13.3 at Cathode. For Vessel compost samples it has decreased from 5.8 to 4,1 at Anode and increased from 5.2 to 12.1 at Cathode. Fig 3 and 4 present the pH of MSW and Vessel Compost samples from Day 1 to Day 11.



**Figure 3:** pH of MSW Compost samples at Anode and Cathode



**Figure 4:** pH of Vessel Compost samples at Anode and Cathode

It is observed due to reduction at the Cathode and oxidation at Anode, pH changes have been observed in the compost samples. MSW compost has shown decreasing concentration of pH at Anode when compared. The pH at Anode on Day 01 was slightly towards alkaline but decreased over time to 6.7, which is Acidic at the end of Day 11. This is due to more  $H^+$  ions that were released by the Anode electrode due to electrolysis reaction. Day 09 has seen the highest number of  $H^+$  ions released changing the pH to 6.6. In the case of the Vessel Compost samples the pH on Day 01 was 5.8 at Anode, which was acidic and gradually decreased to stronger acidic front having pH 4.1 on Day 11. A gradual increase was observed in Vessel Compost cathode samples from Acidic to very strong alkaline with pH 5.2 to 12.1. Both the compost samples have demonstrated that due to the charge and variation in time, there is a polarization of pH at Anode and Cathode, where Anode has shown acidic conditions and cathode alkaline.

**Trace Metals Concentrations** Compost is the means of adding organic matter and suitable structure to the Soil, which is lost during intense agriculture practice. Soil organic matter is managed by using Compost which is a key for sustainable agriculture (Mohammad et al., 2004). A possible drawback in the application of compost to soil could be the release of toxic metal and their distribution to the food chain (Petrizzelli, 1996). The source of low concentrations of toxic metals which might adversely affect the growth of plant and animal health is Compost from MSW. The metal concentrations of 10 elements Zinc (Zn), Nickel (Ni), Lead (Pb), Copper (Cu), Chromium (Cr), from MSW Compost and Vessel compost samples are measured as part of the electrokinetic experiment.

**Table 1.0** Concentration of Metals on Day1 and Day 11 of the experiment

	MSW Compost				Vessel Compost			
	Anode		Cathode		Anode		Cathode	
	Day 1	Day 11	Day 1	Day 11	Day 1	Day 11	Day 1	Day 11
<b>Chromium (Cr)</b>	79.74	938.19	42.7	39.58	202.91	1543.10	34.51	15.46
<b>Copper (Cu)</b>	123.11	220.87	154.23	108.39	11.91	41.19	13.54	38.87
<b>Nickel(Ni)</b>	11.13	20.60	10.26	13.14	10.09	26.689	5.07	6.12
<b>Lead (Pb)</b>	37.52	45.52	48.60	39.45	5.97	5.54	3.90	3.25
<b>Zinc(Zn)</b>	156.31	218.10	193.86	147.88	29.83	70.28	25.35	27.12

Accumulation of metal was found to be more on Day 11 at Anode end of both MSW and Vessel compost samples, this is due to the decrease of pH on Day 11 from Day 1. When the pH has decrease from Day 1 to Day 11, the accumulation percentage has increased at the Anode end. Table 1.0 presents the concentrations of metals on Day 1 and Day 11 of the experiment.

Chromium accumulation at cathode was lesser than Anode. This could be due to precipitation of  $\text{Cr}^{3+}$  at Anode. The redox potential and pH might have affected the speciation of Chromium, which is predominantly present in the oxidation state of  $\text{Cr}^{3+}$  and  $\text{Cr}^{6+}$ . Concentration of Cr on Day 11 is 938 mg/kg and 1543 mg/kg in MSW and Vessel compost respectively. Copper concentrations were at their highest at the Anode and at their lowest at the Cathode due to the low pH near the Anode this could be due to negative complexation or precipitation. Cu concentration are at 220 mg/kg and 41.19 mg/kg respectively at acidic front of both the samples. Nickel concentration behavior could be due to the formation of non-conductive precipitates which retard the migration of ions that ultimately would reduce the mobilization. Though the accumulation of Lead is very minimal when compared to control sample, due to low pH the overall solubility of Pb has increased which shows significant concentration of Pb at the Anode with concentration reaching 45.52 mg/kg. Same is the case with Zinc which may yield soluble zinc compounds at the acidic anode front. Zn Concentration on Day 11 was 218 mg/kg on final day. The highest concentrations of Zn, Cu, Cd, Pb, Ni and Cr were observed in acidic conditions, when evaluating the influence of pH on the release of metals from metallurgical slag. This could be due to dissolution/precipitation of mineral phases and sorption/desorption (Król et al., 2020)

## CONCLUSION

The study concluded that pH please a crucial role in the enhancing the availability of trace metal. This is due to electrolysis of water which released  $\text{H}^+$  ions at Anode due to oxidation resulting in formation of acidic front at the Anode. Due to influence of pH in the electrokinetic treatment the concentration of Chromium, Copper, Nickel, Lead and Zinc has substantially increased after the Electrokinetic treatment on compost.

## REFERENCES

- UN. (2015, September 25). Transforming our world: The 2030 Agenda for Sustainable Development. New York: United Nations.
- DEFRA. (2013, February 27). Mechanical Biological Treatment of Municipal Solid Waste. [www.defra.gov.uk](http://www.defra.gov.uk), <https://www.gov.uk/government/publications/mechanical-biological-treatment-of-municipal-solid-waste>
- Elicker. C., P. F. (2014). Electroremediation of heavy metals in sewage sludge. Brazilian Journal of Chemical Engineering, 31(02), 365 - 371.
- Yuchen Wang, A. L. (2021). Remediation of heavy metal-contaminated soils by electrokinetic technology: Mechanisms and applicability. Chemosphere, 265.
- Yeung, A. T. (1994). Chapters, Electrokinetic flow processes in porous media and their applications. Adv. Porous Media, 2.
- Reddy, K. R., & Saichek, R. E. (2003). Effect of Soil Type on Electrokinetic Removal of Phenanthrene Using Surfactants and Cosolvents. Journal of Environmental Engineering, 129(4), 336-346.
- Petruzzelli, G. (1996). Heavy Metals in Compost and their Effect on Soil Quality. In S. P. de Bertoldi M., The Science of Composting (pp. 213-). Springer, Dordrecht.
- Król, A., Mizerna, K., & Bożym, M. (2020). An assessment of pH-dependent release and mobility of heavy metals from metallurgical slag. Journal of hazardous materials, 384, 121502.