

# Effects of mining activities on Nano-soil management using artificial intelligence models of ANN and ELM

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**Abstract.** Mining of ore minerals (sفالرite, cinnabar, and chalcopyrite) from the old mine has led in significant environmental effects as contamination of soils and plants and acidification of water. Also, nanoparticles (NP) have obtained global importance because of their widespread usage in daily life, unique properties, and rapid development in the field of nanotechnology. Regarding their usage in various fields, it is suggested that soil is the final environmental sink for NPs. Nanoparticles with excessive reactivity and deliverability may be carried out as amendments to enhance soil quality, mitigate soil contaminations, make certain secure land–software of the traditional change substances and enhance soil erosion control. Meanwhile, there's no record on the usage of Nano superior substances for mine soil reclamation. In this study, five soil specimens have been tested at 4 sites inside the region of mine (<100 m) to study zeolites, and iron sulfide nanoparticles. Also, through using Artificial Neural Network (ANN) and Extreme Learning Machine (ELM), this study has tried to appropriately estimate the mechanical properties of soil under the effect of these Nano particles. Considering the RMSE and R2 values, Zeolite Nano materials could enhance the mine soil fine through increasing the clay-silt fractions, increasing the water holding capacity, removing toxins and improving nutrient levels. Also, adding iron sulfide minerals to the soils would possibly exacerbate the soil acidity problems at a mining site.

**Keywords:** ANN; artificial intelligence models; ELM; management; mining activities; nano-soil; toxin

## 1. Introduction

Environmental concerns are becoming a popular subject of discussion these days. Industries are required to eliminate waste from both production and consumption, which in high concentrations, may harm the environment's ecological function (Shariati *et al.* 2011a, 2019e, Ziaei-Nia *et al.* 2018, Trung *et al.* 2019, Afshar *et al.* 2020, Fan *et al.* 2020). Toxins in trash are harmful to soil and groundwater microorganisms, and will have a substantial impact on the ecological balance (Nosrati *et al.* 2018, Milovancevic *et al.* 2019, Sajedi *et al.* 2019, Dong *et al.* 2021, Li *et al.* 2022b, Xu *et al.* 2022b). As a result, waste must be adequately managed such that the toxins are destroyed or reduced to levels below the allowable limit (Shariati 2008, *al.* 2011d, 2019c, Hamidian *et al.* 2011, Toghroli *et al.* 2017, 2018b, 2020a, Li *et al.* 2019, Hosseini *et al.* 2021, Mehrabi *et al.* 2021). Mining operations have long been a source of worry

because of the temporary environmental harm they create (Shariati *et al.* 2012c, d, 2013, 2014a, 2017, Liu *et al.* 2020a). Heavy metal contamination of soil and groundwater is most visible at mining sites and their surrounding areas. Cobalt, nickel, zinc, cadmium, iron, and other metal pollutants are among them. Because of their existing degree of pollution by contaminants, 342,000 sites in Europe and 350,000 sites in the United States are assessed to be in urgent need of cleanup. Due to the enormous number of sites, high cleanup costs become a concern. It is vital to identify suitable and practical strategies or solutions that are both effective and economical in order to support rapid execution and development of remediation technologies (Thomé *et al.* 2015, Shah *et al.* 2016c, Shahabi *et al.* 2016b, Davoodnabi *et al.* 2019, Shariati *et al.* 2020l, Nouri *et al.* 2021). Chemical, physical, and biological methods are now used to remediate contaminated ex-mine site environments (Habibi *et al.* 2016b, 2018, Ebrahimi *et al.* 2019, Esmailpoor Hajilak *et al.* 2019, Qi *et al.* 2019). Isolation, immobilization, toxicity reduction, physical separation, and extraction are used to “separate” the pollutants from their surroundings (Evanko *et al.* 1997, Arabnejad Khanouki *et al.* 2010b, Abdolrahim 2012, Khorami *et al.* 2017a, b, Zandi

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et al. 2018, Shariati et al. 2020m). The procedures used are mostly determined by the metals or chemical impurities to be eliminated (Fanaie et al. 2017a, b, Jahanbakhti et al. 2017, Kazerani et al. 2017, Najarkolaie et al. 2017). The approaches might be classed as in situ or ex situ general. Firstly, the approach addresses the issue by pumping soil or groundwater out of the site and then treating it, while the second approach involves directly injecting or providing treatment chemicals into the polluted area. Until 1992, the ex situ approach was the most common. However, it is not always effective and requires a significant amount of time to operate well. Many academics have shifted their focus to in situ cleanup approaches that are more cost-effective and faster than ex situ remediation (Mueller et al. 2010, Habibi et al. 2016a, 2019b, 2021c, Pourjabari et al. 2019). Nanotechnology is a novel potential technique for in situ cleanup that is touted to be low-cost and low-risk (Shariati et al. 2020a, b, f, i, 2021c). Nanomaterials have been found to be capable materials or catalysts for a variety of applications in the environmental and energy sectors (Kumpiene et al. 2008, Yunus et al. 2012, Moayedi et al. 2019, Mohammadi et al. 2019, Habibi et al. 2020, Shariati et al. 2020g). The phrase “environmental catalysis” denotes to the employment of catalysts in processes say, the emission abatement, waste remediation, and environmentally friendly chemical synthesis to address environmental issues. Nano catalysts have the potential to improve energy and material efficiency, as well as reduce chemical waste and improve waste treatment (Shariati et al. 2010, Shariati et al. 2012b, Ali 2012, Ismail et al. 2018, Wei et al. 2018, Moayedi et al. 2020, Oyarhossein et al. 2020, Hashemi et al. 2021, Moayedi et al. 2021, Cheshmeh et al. 2022). Nanomaterials such as metal oxides, titanium dioxide, noble metals, nanoscale zeolites and carbon nanotubes have shown tremendous promise as adsorbents for adsorption-based remediation of polluted soils and groundwater (Shariati 2013, 2020h, t, Hosseinpour et al. 2018, Naghipour et al. 2020a, Al-Furjan et al. 2021c, Najaafi et al. 2021, Shamsaddini Lori et al. 2021). Groundwater and contaminated soil might be remedied more rapidly and cost-effectively using these nanoparticles. Nanomaterials' well-known advantages are their high surface-to-volume ratio, and crucial ability to absorb (Habibi et al. 2019c, Safarpour et al. 2019a, Al-Furjan et al. 2020b, Ebrahimi et al. 2020, Guo et al. 2021b, Liu et al. 2021a, 2022a). Nanoparticles may also go farther and have a better particle dispersion than bigger particles (Habibi et al. 2019a, Safarpour et al. 2019b, Alipour et al. 2020, Bai et al. 2020, Al-Furjan et al. 2021b, d, Zhang et al. 2021b). Because of their microscopic size, they may fit into even the smallest holes in the subsurface and stay floating in groundwater. This feature is ideal for in situ groundwater remediation, in which no groundwater is pumped out and no dirt is transported to other locations (Otto et al. 2008, Habibi et al. 2017, 2021b, Safarpour et al. 2018, Chen et al. 2022, Xu et al. 2022a). Metal oxide nanoparticles, zeolite nanomaterials, carbon nanotubes, and nanoscale zero-valent iron (nZVI) are the most frequent nanoparticles studied for addressing soil and groundwater contamination (Safa et al. 2019, Shariati et al. 2019a, 2020j, s, Suhatriel et al. 2019, Jahandari et al. 2021). In the next part, we will briefly cover the use of various

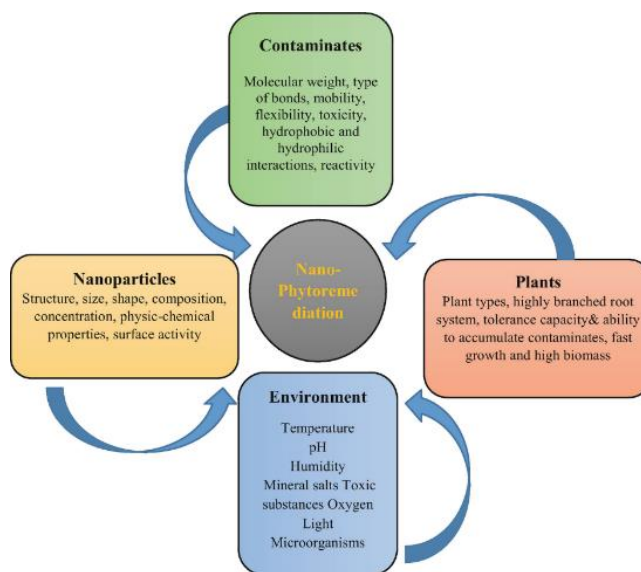


Fig. 1 Nano-phytoremediation of pollutants from contaminated soil environment: Current scenario and future prospects

kinds of nanomaterials in soil and groundwater remediation, and their environmental effect. Fig. 1 shows Nano-phytoremediation of Pollutants from Contaminated Soil Environment: Current Scenario and Future Prospects.

Soil is essential for agricultural development because it allows plants to absorb nutrients (Parikh et al. 2012, Zhang et al. 2019). Agriculture, in reality, nourishes and defines human life; unfortunately, it often disrupts natural ecosystems (Mohammadhassani et al. 2013b, 2014a, Heydari et al. 2018, Shariat et al. 2018, Luo et al. 2019, Xie et al. 2019). For a long time, there has been a contradiction between the advantages and the sustainable management of agricultural land and its protection in the literature (Pretty et al. 2014, Struik et al. 2017, Ghazanfari et al. 2020, Ebrahimi et al. 2021, Safarpour et al. 2021, Shariati et al. 2021a). Land contamination puts people's quality of life, livelihoods, and long-term development at risk (Martin et al. 2016, Adamian et al. 2020, Al-Furjan et al. 2021a, Dai et al. 2021b, Qi et al. 2021, Li et al. 2022c). Regarding the demands of expanding population and the decreasing of arable lands due to technogenic activity, soil conservation is the most important parameter for the contemporary period. Nanotechnology breakthroughs have created a worldwide window for effectively remediating or restoring damaged soil (Khanouki et al. 2016, Shah et al. 2016a, b, 2018, Medina-Pérez et al. 2019, Naghipour et al. 2020b, Rajput et al. 2022). Nanotechnology has been touted as having significant promise as an ecologically friendly technology, particularly in terms of reducing the toxicities of certain metals/metalloids (Shah et al. 2015, Chen et al. 2019, Razavian et al. 2020, Shariati et al. 2020k, Raffa et al. 2021, Kumari et al. 2022). Nanotechnology has also been identified as a possible approach for pollution cleanup in a number of environmental matrices along with soils (Rajput et al. 2022, Zhang et al. 2022). The optimal soil for plant health and development is said to be one that is rich in key minerals and micronutrients (McGrath et al. 2014,

Khanchoul *et al.* 2020, Williams *et al.* 2020, Amadu *et al.* 2021, Kazapoe *et al.* 2021). Human-made activities have presently contaminated the soil with a range of persistent organic compounds, including HMs (Hg and Pb), PCBs, PAHs, VOCs, agrochemicals (fertilizers, fungicides, and pesticides), and occasionally excess nutrients (Al-Furjan *et al.* 2020a, Zare *et al.* 2020, Chen *et al.* 2021, Huang *et al.* 2021b, Liu *et al.* 2021b, Gorovtsov *et al.* 2022). Subsequently, urbanization and industry have polluted the environment and agricultural land with solid wastes, various chemicals, and solvents (Rajput *et al.* 2018) (Liu *et al.* 2020c, Habibi *et al.* 2021a, He *et al.* 2021, Zhang *et al.* 2021c). Nano bioremediation is a low-cost method of breaking down toxic chemicals using plants and bacteria, which improves soil quality and reduces pollution. The procedure can eliminate, preserve, or decrease the quantity of pollutants existing in the soil by decomposing contaminants in the soil (Shariati *et al.* 2012a, 2015, 2016, Chandra *et al.* 2017, Paknahad *et al.* 2018, Sobia *et al.* 2019). There have been attempts in the past to increase bioremediation efficiency by the use of chemical additives or biotechnology (Gerhardt *et al.* 2017), but nanotechnology has now brought a new level of complexity to the process. Heavy metals mostly harm plants and lower soil creatures by causing the production of reactive oxygen species (ROS) that triggers macromolecules like proteins and nucleic acids to be damaged (Jaishankar *et al.* 2014, Akter *et al.* 2019). Site stabilization is one of the most important ways for removing HMs because it immobilizes them at a particular location, reducing their mobility and availability in the soil and preventing them from leaking across sites (Suman *et al.* 2018, Liu *et al.* 2020b, Shariati *et al.* 2020c, d, e, Toghroli *et al.* 2020b, Zhou *et al.* 2020, Dai *et al.* 2021a, Shao *et al.* 2021, Wu *et al.* 2021). Site stabilization is one of the most important ways for removing HMs because it immobilizes them at a particular location, reducing their availability and mobility in the soil and preventing them from leaking across sites (Shariati 2014, 2021b, Suman *et al.* 2018, Qi *et al.* 2022). Biogenic NPs, in particular, have garnered a lot of interest for their ability to eliminate HMs (Shariati *et al.* 2011b, 2014b, Khorramian *et al.* 2015, Tahmasbi *et al.* 2016, Nasrollahi *et al.* 2018, Rajput *et al.* 2021). Biogenic NPs are those that are produced by living organisms. *Morganella psychrotolerans* (Capeness *et al.* 2019, Sharma *et al.* 2019) produces the most well-known biogenic NPs, such as Ag NPs.

### 1.1 Nano-technological approaches for restoring metalloid-contaminated soils

Metalloids, in contrast to metals, exhibit a broad range of characteristics, including those of nonmetals and metals. Metalloids are used in a variety of applications. This material occurs naturally, but its concentrations have risen to harmful levels as a result of industrialization (Fordyce *et al.* 2017). Among the elements of the periodic table known as metalloids are silicon (Si), germanium (Ge), antimony (Sb), boron (B), arsenic (As), and tellurium (Te) (Yazdi *et al.* 2016). Silicon (Si) is the most abundant element on the

planet. Environmental contamination with metalloids has a negative impact on human health, plant and animal life, and the ecosystem as a whole. They have the potential to be fatal even at very low doses (Martínez-Alcalá *et al.* 2020, Raffa *et al.* 2021). Even more concerning, the presence of HMs/metalloids in soil has the potential to have a significant impact on the abundance and structure of soil microbial communities (Crowley 2008, Huang *et al.* 2021a). It is possible to remove these metalloids from soil utilizing a number of different remediation techniques. The appropriate rehabilitation of sites polluted by metalloid pollutants is hampered by the fact that metalloid pollutants do not dissolve on their own and that it is not always feasible to collect all of the contaminated soil. As a result of this strategy (Zhang *et al.* 2010), metalloids may be immobilized in soils by adsorption, surface precipitation, structural integration, or ion exchange, hence reducing their bioavailability and bio-accessibility (Kumpiene *et al.* 2008). It is clear that the initial step of phytoremediation, decreasing the toxicity of the soil, is necessary for the establishment of a plant cover over polluted ground. Despite the fact that nanotechnology has a wide range of applications, there are still questions regarding its environmental effect, its long-term viability, and its possible health dangers. Consequently, the primary goal of this section is to provide an in-depth examination of the destiny of NPs as well as the emergence of new environmental challenges associated with their intended emission as a result of their increasing usage, particularly in remedial operations. Recent research has shown that expanding the use of NPs in agriculture has major negative consequences, particularly for the environment. NPs, for example, may cause soil attributes to be changed by a rise in their concentration or an accumulation of their constituents as a result of their intended usage in agriculture (Rajput *et al.* 2020, Kumari *et al.* 2022). Plant growth and development may be hampered by the presence of NPs in the soil, which have been shown to change soil pH (Fernández *et al.* 2009, Struik *et al.* 2017).

### 1.2 Zeolite nanoparticles

Zeolites are minerals that are often used in a wide variety of chemical processes and industries, as well as in many other applications. Zeolites have a lower density than other minerals as a result of the existence of discrete channels and pores in their structure, as opposed to other minerals (Liu *et al.* 2012). Because of their unique properties, zeolite materials may be changed in a variety of ways to boost their activity and selectivity for the removal of a broad range of compounds from aqueous solutions (Inglezakis *et al.* 2004). Zeolites have the benefit of being more readily accessible and less expensive than other nanomaterials when compared to other nanomaterials (Eyde 2010). Adsorption procedures involving the absorption of anions from effluents are often used in the treatment of contaminants employing modified natural zeolites (Haggerty *et al.* 1994). Its capacity to hydrate and dehydrate as well as exchange cations with aqueous solutions without degrading its structural stability is one of its distinguishing

characteristics. It is possible for them to have large cation exchange capacities, which may range between 200 and 300 cmolkg<sup>-1</sup> (Ming *et al.* 2001). A significant difference between zeolite and other soil remediation nanomaterials is that it has a significant impact on both physical and chemical characteristics of the soil (Liu *et al.* 2012). Former mine soil has a high bulk density and a low water retention capacity, making it an excellent choice for landscaping. Zinc nanoparticles remove contaminants from the soil and improve the clay and silt fractions as well as the soil's water-holding ability, allowing the soil to regain its fertile status (Ming *et al.* 2001). As seen by the previous instances, particle structure and size are crucial for improving soil quality and fertility (Liu *et al.* 2012). Due to its low density, zeolite is a better option for growth than other soil types because it minimizes the total density of the soil. Both the pH of the soil and the nutrient retention capacity of soil may be improved as a result of the presence of zeolites (Ming *et al.* 2001). The cation exchange capacity of zeolite allows H<sup>+</sup> ions to interact with Ca<sup>2+</sup> ions, which is important in acid soil remediation. In contrast, the liming ingredient has a stronger effect, indicating that they should be used in conjunction with one another (Liu *et al.* 2012). Since the beginning of time, the high cation exchange capacity of zeolites has been the driving force behind their use as fertilizers, but it is also the primary rationale for their employment in the treatment of chemical wastes." The bulk of natural zeolites favor cations with low charge density and low hydration energy are characterized by low charge density and low hydration energy (Colella 1996). Ming and Allen have investigated the potential of natural and artificial zeolites as a heavy metal cleanup agent in soil, and their findings have been published (2001). Many times, zeolites function by immobilizing heavy metals and decreasing the capacity of plants to absorb them. Using Ca-type zeolites rather than Na-type zeolites for revegetation of contaminated soil, Liu and Lal found that the former is preferable (2012) (Liu *et al.* 2012). A number of additional investigations have shown that zeolites are capable of extracting hazardous elements such as cadmium, chromium, nickel, lead, and zinc from solid wastes since the publication of Zorpas *et al.* (Zorpas *et al.* 2000). According to Xiong *et al.* (2019), zeolites raise the pH of the soil while lowering the amount of exchangeable Cd in the soil. Furthermore, it has been demonstrated that Nano zeolites have a greater impact on soil remediation than standard zeolites in some studies (Xiong *et al.* 2015). When it comes to the cleaning of industrial and municipal pollution, zeolites are often employed since they are believed to be especially cost-effective (Liu *et al.* 2012). It has been discovered, however, that heavy metals may be removed from ex-mine soil by using zeolites' ion exchange capacity and selectivity for heavy metals in combination with other methods.

### 1.3 Nano-bioremediation of heavy metals

Most of the responsibility for the prevalence of HMs in the environment may be attributed to increased human activity. In contrast, disrupted biogeochemical cycles are

responsible for the release of pollutants into the environment as a result of their discharge into the ecosystem. Elements such as arsenic, cadmium, copper, lead, mercury, and uranium have no biological functions in the biological system. High-level heavy metal pollution is a significant source of organic pollution since they have detrimental impacts on the biota even at low concentrations (Alissa *et al.* 2011, Gairhe *et al.* 2021). In terms of toxicity, the bioavailability and absorption of HMs play an important role (Rasmussen *et al.* 2000). Toxicity to heavy metals (HM) is increased in acidic environments, especially when the soil structure is poor and nutrients are few (e.g., mining sites) (Mukhopadhyay *et al.* 2010). Heavy metals mostly affect plants and lower soil organisms by triggering the creation of reactive oxygen species (ROS), which degrade macromolecules such as proteins and nucleic acids (Jaishankar *et al.* 2014). The presence of heavy metals (HMs) in the soil has an effect on crops and plants, as well as on the nutritional quality and ecological characteristics of such crops and plants. Aspects of crop growth that are affected by HMs include crop species, soil physicochemical parameters, and HM type (Chaplygin *et al.* 2021). The main mechanism of toxicity conferred by HMs on agricultural plants is the generation of reactive oxygen species (ROS), which damages cell organelles, macromolecules such as proteins and nucleic acids, as well as other components of the plant's structure and function (Huang *et al.* 2019, Chaplygin *et al.* 2021). The disruption of respiration and photosynthesis, as well as lower enzyme activities and increased oxidative stress have all been demonstrated (Arif *et al.* 2016, Enez *et al.* 2018). It has also been shown to reduce biomass and crop production while altering the quantity, activity, variety, and genetic composition of beneficial soil microflora have also been demonstrated (Arif *et al.* 2016, Enez *et al.* 2018). Because it immobilizes HMs at a specific area, decreasing their mobility and availability in the soil, and preventing them from leaking across sites, site stabilization is one of the most essential methods for eliminating HMs. The use of various nanoparticles, notably biogenic nanoparticles, has received a great deal of interest for the removal of HMs (Rajput *et al.* 2021). The term "biogenic NPs" refers to those that are generated by living organisms. It has been shown that *Morganella psychrotolerans* may create well-known biogenic NPs such as silver nanoparticles (Capeness *et al.* 2019, Sharma *et al.* 2019).

## 2. Methodology

### 2.1 Soil sampling

The rocks in the study region are rich in mineral deposits, making the area an attractive place for gold mining, especially small-scale mining due to the abundance of mineral deposits. The area is an excellent location for investigating how small-scale mining activities influence soil and, as a consequence, agricultural production in the surrounding community. The soils found in the study (Forest Ochrosols) (Wills 1962) are the most prevalent kind

of soil. It is estimated that the pH of soils varies from 4.6 to 5.0. The Hygropeds suborder of the Latosol soil family group is home to the Asikuma series of soils, which are a subset of the Hygropeds suborder. Located in a semideciduous forest zone, the area receives total annual mean rainfall ranging from 1200 to 2000 mm with average temperatures ranging from 24 to 29 degrees Celsius (Adu-Gyamfi 2014). The soils used in the experiment were gathered from 14 different places throughout the world. In mined areas, there were ten sample locations, while in unmined areas, there were four sample locations. Across each of the mined and unmined study sites, a belt transect of 200 m by 200 m was constructed. Using a belt transect, each plot was divided into 16 equal-sized plots of 50 m × 50 m each. During the course of the study, 11 belt transects (200 metres by 200 metres each) were constructed in mined areas, while 5 belt transects (200 metres by 200 metres each) were constructed in unmined research locations. The soil pH was defined by using a pH meter (Orion star, A211 by Thermofisher Scientific Inc., NY) as described by summer.

## 2.2 Artificial neural network (ANN)

### 2.2.1 MLP-type neural networks

In recent decades, with the increased usage of computers and, as a result, the deployment of more complicated statistical techniques (MOGHADAM *et al.* 2010, Asadolahi *et al.* 2020, Ghanbari-Ghazijahani *et al.* 2020, Partovi *et al.* 2020), researchers have attempted to investigate multivariate correlations between output and input variables in greater depth (Toghroli *et al.* 2014, Safa *et al.* 2016, Sedghi *et al.* 2018, Katebi *et al.* 2019, Shariati *et al.* 2020o, Zhang *et al.* 2021a). With the increasing accuracy and precision of analytical measuring methods, it has become clear that all effects of interest cannot be accurately described by simple univariate and even linear multivariate correlations, a set of methods that have recently become very popular as artificial neural networks (ANNs) (Mohammadhassani *et al.* 2013a, Toghroli *et al.* 2016, Sadeghipour Chahnasir *et al.* 2018, Safa *et al.* 2020b, Shariati *et al.* 2020q). The nature of the issue we're attempting to solve is that whether in using ANNs, the problem needs a supervised or unsupervised approach (Mohammadhassani *et al.* 2014b, Shariati *et al.* 2019d, 2020n, p, 2021d). The supervised issue implies that the chemist already has a series of experiments with known results for specified inputs, while the unsupervised problem implies that the researcher is dealing with a collection of experimental data without any specific related responses (or extra information) (Shariati *et al.* 2011c, 2019b, Sinaei *et al.* 2011, Shahabi *et al.* 2016a, Khorramian *et al.* 2017). Unsupervised difficulties often emerge when a chemist must investigate experimental data obtained during pollution monitoring, or when he or she is confronted with measured data for the first time, or when a suitable approach to show the data in the most appropriate manner is required (Arabnejad Khanouki *et al.* 2010a, Mojtaba 2011, Sinaei *et al.* 2012, Shariati *et al.* 2020r, Davoodnabi *et al.* 2021). Unsupervised approaches are usually required to solve the early challenges connected with data management.

Only once we have gained a better understanding of the measurement space (measurement regions) of input and output variables, as well as the responses' behaviors, we can pick sets of data on which supervised techniques (for example, modelling) may be used. The following are the primary categories of objectives or challenges in analytical chemistry for which ANNs may be used: Unknown function approximation has piqued the curiosity of statisticians, data scientists, and engineers (Aghakhani *et al.* 2015, Toghroli 2015, Wang *et al.* 2020, Guo *et al.* 2021a, Huang *et al.* 2021c, Zhao *et al.* 2021). ANNs are a sort of function assessment that provides a framework for learning any function from input dataset via a training procedure (Hou *et al.* 2021, Huang *et al.* 2021d, Jiao *et al.* 2021, Liu *et al.* 2021c, Ma *et al.* 2021, Moradi *et al.* 2021, Xu *et al.* 2021). One of the most essential aspects of a neural network (NN) is its flexibility and ability to learn difficult correlations from input (Mohammadhassani *et al.* 2015, Toghroli *et al.* 2018a, Sari *et al.* 2019, Xu *et al.* 2019, Safa *et al.* 2020a). The feedforward multi-layer perceptron is the most popular neural network architecture (MLP) (Luo *et al.* 2022, Yang *et al.* 2022, Yu *et al.* 2022, Zhu *et al.* 2022). Once the layers' number and neurons in each layer were determined, the network's weights should be changed to reduce the network's prediction error. This is the overarching function of the learning models. Back-propagation (BP) is the most extensively used learning procedure in NNS, and it is employed to train the ANN in this study. The multilayer perception (MLP) is a simple and practical kind of feed forward ANN. The prediction data is sent through the input layer to the accessible neurons in the following (hidden) layer. In the input layer, biases are added, weights are multiplied, and a net value is produced as Eq. (1):

$$Net = \sum_{i=1}^n w_{ij}x_i + b_j \quad (1)$$

$x_i$  = nodal variables in previous layer

$n$  = all nodal variable' numbers received from the previous layer

$w_{ij}$  &  $b_i$  = the weights and biases of network in the current layer

Following the report of output signal  $y$ , an activation function is used to reduce the net values' variation. The tangent hyperbolic function provides the most reliable activation capabilities, according to Eq. (2).

$$y = f(Net) = \frac{2}{1 + e^{-2 \cdot Net}} - 1 \quad (2)$$

This process is continued for each layer of MLP until the final layer's output signals are provided (predicted values). Later, the results were computed and compared. Finally, one ideal strategy is used to lower the error variable by changing the given biases and weights using MLP. The training process might be done using a number of approaches; however, due to the quick convergence and precision of BP model, ANN is employed in this study.

### 2.3 Extreme learning machine (ELM)

Li *et al.* (2012) pioneered the use of the extreme learning machine (ELM) as a single layer feed forward

neural network (SLFN) in 2006. Any continuous function on any compact input set may be computed by a single SLFN with random biases and weights (Huang et al. 2011). It was estimated that the input biases and weights of one SLFN could be randomly selected, and the output weights of the SLFN could be calculated mathematically according to the input. Using this concept to determine the SLFN's biases and weights resulted in a quick learning model, with ELM defining all network variables and minimizing redundant human interferences (Li et al. 2021, Liu et al. 2021d, e, Zhan et al. 2022). An ELM model is developed in three stages: 1) the formation of the SLFN, 2) the random selection of the network's biases and weights and 3) calculation of output weights by inversion of the hidden layer output matrix [42, 66] (Feng et al. 2012). One SLFN with  $L$  hidden nodes is theoretically investigated for a dataset with  $m$ -dimensional target vectors,  $N$  training samples, and  $n$ -dimensional input vectors (Zheng et al. 2013).

$$\sum_{i=1}^L \beta_i G(w_i \cdot x_j + b_i) = o_j \quad j = 1, 2, 3, \dots, N \quad (3)$$

$G$  = activation performance

$w_i = [w_{i1}, w_{i2}, \dots, w_{in}]^T$  = weight vector connecting  $i^{th}$  input neurons to hidden neuron

$x_j = [x_{j1}, x_{j2}, \dots, x_{jm}]^T$  = input vector

$\beta_i = [\beta_{i1}, \beta_{i2}, \dots, \beta_{im}]^T$  = weight vector connecting output neurons to hidden neurons

$b_i = [b_{i1}, b_{i2}, \dots, b_{im}]^T$  = bias vector

$o_j = [o_{j1}, o_{j2}, \dots, o_{jm}]^T$  = output vector

Supposing that one SLFNN with activation function  $G$  and  $L$  hidden neurons could calculate the targets ( $t_j$ ) with 0 error e.g.  $\sum_{j=1}^L \|o_j - t_j\| = 0$ , Eq. (4) could be as Eq. (5):

$$\sum_{i=1}^L \beta_i G(w_i \cdot x_j + b_i) = t_j \quad (5)$$

$j = 1, 2, 3, \dots, N = [t_{j1}, t_{j2}, \dots, t_{jm}]^T$  = target vector

Also, this  $N$  equations could be compactly written as  $t_j$

$$H\beta = T \quad (6)$$

$$H = \begin{bmatrix} G(w_1 \cdot x_1 + b_1) & \dots & G(w_L \cdot x_1 + b_L) \\ \vdots & \dots & \vdots \\ G(w_1 \cdot x_N + b_1) & \dots & G(w_L \cdot x_N + b_L) \end{bmatrix}_{N \times L} \quad (7)$$

and

$$\beta = \begin{bmatrix} \beta_1^T \\ \vdots \\ \beta_L^T \end{bmatrix}_{L \times m} \quad \text{and} \quad T = \begin{bmatrix} t_1^T \\ \vdots \\ t_N^T \end{bmatrix}_{N \times m} \quad (8)$$

Output weights are gained if the minimal differential between the right side (target variables and the left side (predicted variables) of Eq. (9) is occurred i.e.,  $\min \|H\beta - T\|$ . Also, it was proved that when the output weight is as

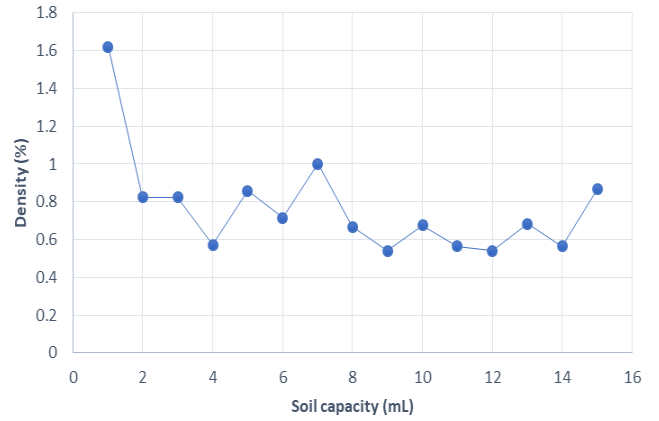


Fig. 2 Traditional change substances and enhancement of soil erosion

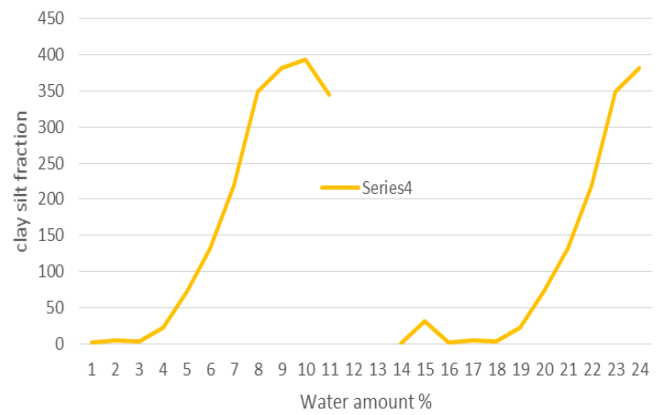


Fig. 3 Enhancing the mine soil fine by increasing the clay-silt fractions and increasing the water capacity in Zeolite Nano materials

follows, the least error between the predicted variables and target variables are occurred:

$$\hat{\beta} = H^\dagger T$$

$\hat{\beta}$  = output weight vector

$H^\dagger$  = Moor-Penrose generalized inverse matrix

$T$  = target vector

Because there is no optimization method in ELM, human interferences and training time are decreased significantly.

### 3. Result and discussion

#### 3.1 Model performance indicators

Based on derived data, for comparing the results of our hybrid, the regression indices of determination coefficient ( $R^2$ ), root mean square (RMSE), and Pearson correlation coefficient ( $r$ ) were applied through MATLAB.

$$R^2 = \frac{[\sum_{i=1}^N (O_i - \bar{O}) \cdot (P_i - \bar{P})]^2}{\sum_{i=1}^N (O_i - \bar{O}) \cdot \sum_{i=1}^N (P_i - \bar{P})} \quad (10)$$

$$RMSE = \sqrt{\sum_{i=1}^N \frac{1}{N} (O_i - P_i)^2}$$

- $P_i$  = predicted values in sample  $i$
  - $O_i$  = observed values in sample  $i$
  - $P$  = predicted values
  - $O$  = observed values
  - $\bar{P}$  = predicted values
  - $\bar{O}$  = mean of observed variables
  - $N$  = number of training or testing samples
- (11)

### 3.2 Developing of ELM-ANN

On real-world software datasets, the characteristic of ANN-ELM for the regression venture turned into provided. Each test turned into one hundred times, and the findings stated in averagely 50 trials. In this study, 50 neurons have been identified. The preliminary of nodes' variety turned into determined via experimental trial and errors method primarily based totally on the quantity of the incoming data, as stated in ELM. Due to the removal of redundant or inactive hidden nodes, ANN-ELM improves accuracy. A trial-and-blunders technique has been achieved to locate the neurons' number. Then, the characteristic of ELM changed into tested in training and checking out stages via the means of RMSE. For example, the use of the traditional ELM, the dataset of delta elevators with 3000 starting nodes generated an RMSE of 0.5643, while ANN-ELM produced an RMSE of 0.4527. Furthermore, compared to standard ELM, the time needed for training of ANN-ELM is minimum. ANN can lessen needless nodes whilst maintaining ELM's excessive overall performance in a brief training period. In summary, the findings proven in Table 1 display that ANN-ELM reduces version overfitting. The data derived from those techniques have been analyzed to decide their distribution intervals while being normalized inside the interval of zero and 100 that later all have been de-normalized. In this case, the distribution sample of facts become computed through ELM- ANN. The aim of this study is to appropriately examine the facts derived from the techniques to offer a second rotational assessment of the Effects of mining activities on Nano-soil management. Following Fig. 7, the regression line and the red dots are the noises of this assessment. The depth of red noises over the line indicates a higher overall performance of our model in predicting the soil interplay behavior. It shows that any overlap between the line and red dots indicates the closeness (alignment) of the predicted and observed values. Fig. 5 indicates the histogram of the version and error distribution.

The maximum error case become visible in 0-26 with ninety records and the lowest error is in 125- 134 with 2 records. Fig. 7 shows the error frequency of ELM-ANN hybrid. Fig. 8 indicates the 3-d plot of overall performance of ELM- ANN. X axis indicates the nodes of the hybrid, and Z axis is the variety of iterations. The maximum error is visible in node three with 67 iterations. Meanwhile,

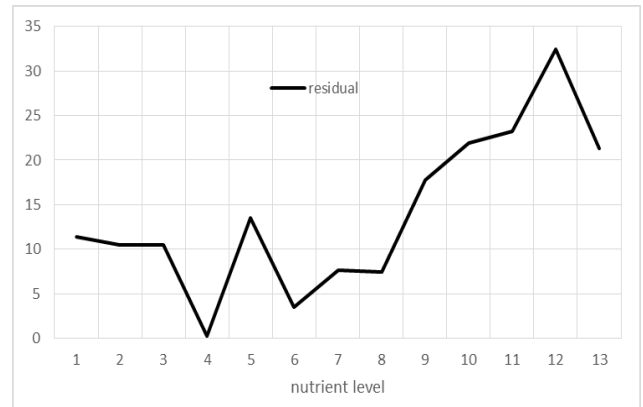


Fig. 4 Removing toxins and improving nutrient levels

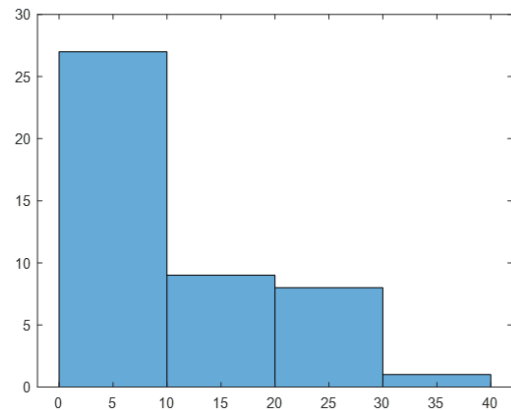


Fig. 5 Histogram ANN-ELM

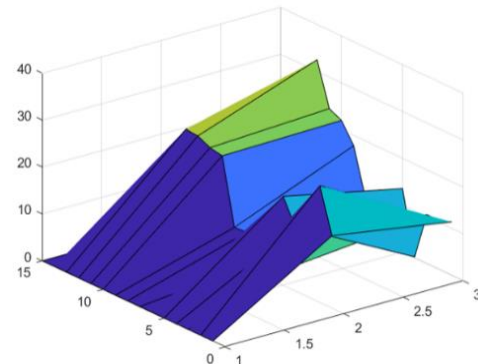


Fig. 6 3D plot of the model

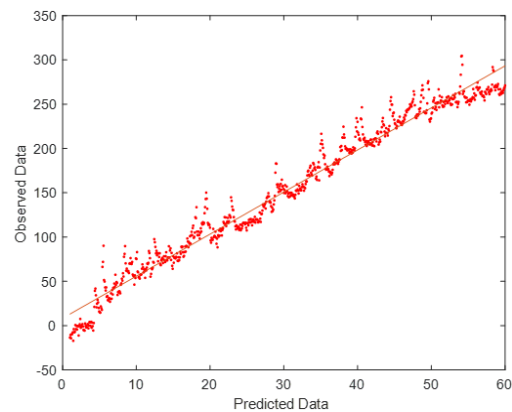


Fig. 7 Error distribution of model

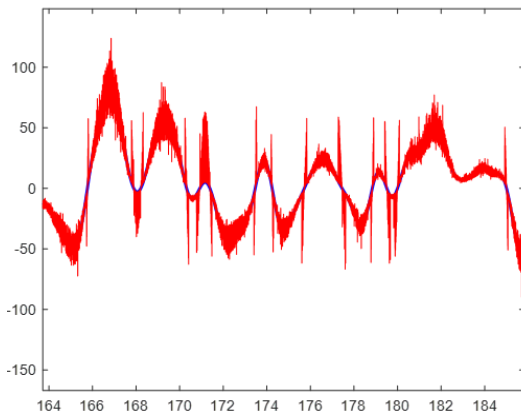


Fig. 8 RMSE of the model

Table 1 Analyzing the testing phase results of ELM- ANN

AI Model	Testing phase		
	RMSE	$r$	$R^2$
ELM- ANN	0.4527	0.5552	0.9977

Fig. 9 indicates the RMSE check values, as a result the RMSE errors are visible among -three hundred and three hundred. Any overlap between the expected value and observed values (blue) indicates the accuracy of the proposed version. In this Figure, there may be a near overlap between values, representing the outperformance of the version. Looking at Table 1, the  $R^2$  of ELM- ANN version as 0.9977 indicates closer to 1. Also, the RMSE (0.4527) indicates higher result in one-layer testing (near zero). By unique evaluation supplied by this hybrid, it is viable to acquire highly correct effects in the direction of the prediction of complex subsidence styles as a result of mining. Therefore, it means that ELM- ANN could be remarkably performed higher.

#### 4. Conclusions

Small-scale mining has had an adverse effect on the quality of the soil in the study area, which is necessary for plant growth. It is possible that mine soil reclamation and rehabilitation may improve local environmental protection, providing more land for forest or agricultural usage, and contribute to the reduction of CO<sup>2</sup> emissions in the atmosphere. However, since highly disturbed land surfaces usually have low soil quality, it is difficult to produce desirable plant species such as trees and crops on these surfaces in the first place. Some industrial, agricultural, and municipal wastes have the potential to be utilized as soil supplements at mining sites to improve soil quality; however, the presence of environmentally sensitive pollutants in these wastes hinders their widespread use. However, despite the fact that there is limited evidence to support this hypothesis, the literature suggests that zeolites, nano iron oxide particles, nano zero valent iron particles, nano-phosphate-based particles, nano-sulfide-based particles, and carbon nanotubes can improve soil physical and

chemical properties, improve soil fertility, stabilize soil contaminants, and reduce soil erosion by improving soil physical and chemical properties, stabilizing soil contaminants, and reducing soil erosion. Positive outcomes have resulted from the bridging of the data gap on real-world remediation, which has been made possible by increased collaboration between academics and business. Because of this, it will be useful in directing future soil cleaning projects, which are sometimes necessary and cannot wait for trial results to be obtained, and which utilize methods that have been created in the meantime. The majority of current Nano bioremediation research is therefore limited to laboratory experiments and computer modelling, which is a significant drawback. As a consequence, multidisciplinary strategies are necessary to repair soils in the field that have been contaminated by a broad range of contaminants. However, before extending the use of Nano bioremediation approaches, it is important to address the long-term fate of nanoparticles (NPs) in the environment.

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