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RESEARCH

Assessment of Pollution Level of Soil Contaminated by Fertilizer Industry Waste

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ABSTRACT

Organic compounds, alcohols, ammonia, nitrates, phosphorous, and suspended solids are the main constituents of waste from the chemical fertilizer industry. Heavy metals are natural constituents of soils and their concentration varies depending on parental materials. In the last years, the content of heavy metals in soils has increased due to distribution of fertilizers waste, pesticides, industries, waste disposal. Due to these activities the life capacity of soils decreased; especially where the natural background is already high because of natural parental material richness in heavy metal. As a matter of fact it is very important to distinguish between the natural background values and anthropogenic inputs, and to understand that the background values change from area to area and with the scale of the area investigated. There is currently a wide variety of methods used to evaluate soil contamination. To evaluate the soil contamination rate Geo-accumulation index (Igeo) can be applied. This index is used to assess the presence and intensity of anthropogenic contaminant deposition on surface soil. Four soil samples collected from different location near fertilizer industry and it was investigated that many constituent present in soil specimen such as (Cd, Mn, Zn, Cu and Pb). Contaminated samples show the moderate to extreme pollution level on the basis of pollution index.

KEYWORDS

Organic substance, fertilizer waste, Heavy metals, contaminated soil, AAS.

INTRODUCTION

Now a days Industrialization and uncontrolled urbanization, environmental problems have increased in recent years. It has become more obvious that the general public and business owners are becoming more conscious of factors that have a detrimental influence on the environment, with water quality being among their top worries. Industrialization, industry expansion, dwindling water sources, and increasing demand for home and industrial operations all contributed to a decrease in water quality. Untreated industrial and urban slum waste discharged into waterways and polluted soil. In India's agriculturally based economy, the fertilizer sector is a significant manufacturing sector. A variety of fertilizer, including those that contain the nutrients nitrogen, phosphorous, and potassium (N, P, K Nitrogenous, phosphate, and potassium fertilizers fuel the growth of the agricultural sector, which is significant). The ammonia plant which is necessary for nitrogen fertilizers as well as acid and solvent plants, including those for phosphoric and nitric acid, as well as various fertilizer units, would be found in a typical fertilizer industry complex. As a result, the wastewater generated by various facilities comprises a range of toxins depending on the source of production, including acids, alcohols, and salts, as well as significantly higher and ammonia Cal nitrogen values. Ammonia, methanol, and other contaminants are present in the wastewater produced by fertilizer plants (Vinay M. Bhandari *at.al*).

Fig. 1. Fertilizer industry. (Source: Google.com)

Typical waste from industry

Over the years, industries have produced enormous amounts of waste continuously. Industrial waste can be biologically accumulative, non-degradable (conservative), or degradable. The variety of this waste makes it difficult to treat it before discharge, which is a problem. In the end, this raises the price of treatment. The present work focuses on waste from the phenol, polyester, and sugar industries as well as trash for heavy metals like Cr, Ni, and Zn. The waste from the fertilizer where these hazardous metals are mostly discovered. These sectors generate trash that has a significantly high. Through a few wastewater tests, the effect of adsorption using carbon slurry as adsorbents on waste investigated.

Fertilizers and their contaminants in soils

According to (Van Breemen *et. al.* 1987), the kind of ammonia and its subsequent modifications may have a substantial impact on how much proton is transported into the soil. Since nitrification of ammonia, nitrification of ammonium, and hydrolysis of urea all add 1H, 2H, and 2H, respectively, the microbial oxidation fertilizer for ammonia are very crucial in this situation. This study aims to investigate how nearby fertilizer industry soils are affected by waste pollutants found in phosphogypsum and pesticides released from the fertilizer industry. The degree of soil trace element enrichment in comparison to regional. They identified the chemical species in the contamination source. As a method for identifying trace element carrier species, relationships behavior between major and trace elements in the soil were examined.

RESEARCH FOCUS

The assessment of pollution levels in soil contaminated by fertilizer industry waste involves analyzing various parameters to determine the extent and severity of contamination.

MATERIALS AND METHODS

Study area

Around the fertilizer plant, the study area covers 1.0 km^2. The factory footprint is divided into two parts: the main unit, which is situated along the coast and produces phosphate fertilizer (PF), sulphuric acid, and phosphoric acid; and the fertilizer factory. It uses a slurry-granulation technique to create granular triple super phosphate (TSP). PG by products are housed near to the raw material storage area (**Fig. 2**). Two wet scrubbers are employed to cut down on fugitive dust and gas emissions brought on by drying, granulation, and acidulation. The exhaust from the scrubbers is discharged into the atmosphere through two chimneys. However, processing and storing raw materials, finished products, and by products outside results in some contaminated dust being discharged into the environment.

Fig. 2. Fertilizer plant through map. (Source: Googlemap.com.in)

Fertilizer industry waste

Fertilizer industry waste generated in Gorakhpur by the fertilizer plant. The quantity of waste depending on the raw material used, the finished product obtained, and the

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process adopted for fertilizer production, the waste discharged from fertilizer industries varies greatly. A 1000 tons per day urea plant with a recirculating cooling water system and all necessary auxiliary facilities typically discharges 8000 to 12000 m3 of waste per day, whereas a phosphate fertilizer plant with a recirculating cooling water system and auxiliary facilities and producing about 100 tons of phosphorus pent oxide (P_2O_5) per day as fertilizer discharge 3000 to 6000 m3 per day.

Fig. 3. Waste generate point.

Main pollutants

The main pollutants from the nitrogenous and phosphate fertilizer industry along with the auxiliary facilities are indicated below.

- Ammonia and ammonium salt
- Suspended solids and ash
- Acids and alkalis
- Oil
- Arsenic
- Nitrates
- Urea

Collection of soil sample

Gathering soil samples from four locations near the Gorakhpur plant's fertilizer industry. Using a clean shovel, the sample was taken from the sample location. Around the sample area, a 15 cm depth soil sample was taken. It was properly mixed, then put into a clean, labeled plastic bag for further examination. After mixing and gradually homogenizing the samples, a 2-mm-mesh sieve was used to separate them. The samples were initially dried by air before being heated in an electric oven for around 30 minutes at a temperature of 40 °C. For digestion, the resulting fine powder will be maintained at room temperature.

Fig. 4. Soil sample collection.

Engineering properties of soil

• **OMC Test:** The optimum moisture content (OMC) or optimum water content (OWC), also known as the maximum dry density (MDD) of the soil, is obtained at this moisture level. This OMC number relates to the precise quantity of soil compaction energy used.

Fig. 5. OMC Test.

Sample No.	MDD(g/cm3)	OMC(%)
1	1.67	18
2	1.69	18.67
3	1.76	20
4	1.72	19.23

Fig. 6. Contaminated sample Maximum dry density (g/cm^3) Vs optimum moisture content (OMC %).

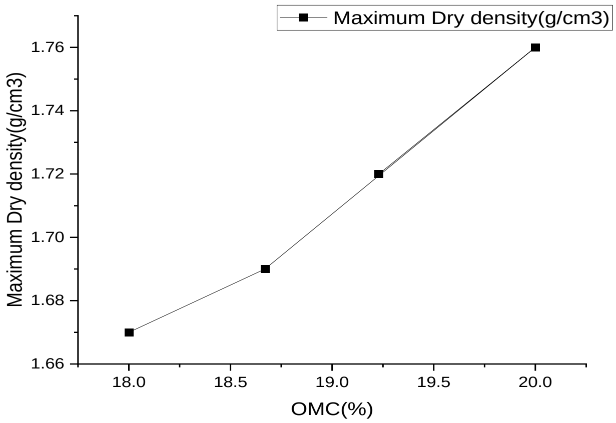

Fig. 7. Contaminated sample Maximum dry density (g/cm^3) Vs optimum moisture content (OMC %).

Geotechnical properties of uncontaminated soil

Table 1. Significance and Testing.

Sample No.	Specific gravity	Liquid limit (%)	Plastic limit (%)	Plasticity index	Maximum Dry density (g/cm^3)	OMC (%)
1	2.71	44	20	24	1.87	17.7

Geotechnical properties of contaminated soil

Table 2. Significance and Testing.

Sample No.	Specific gravity	Liquid limit (%)	Plastic limit (%)	Plasticity index	Maximum Dry density (g/cm^3)	OMC (%)
1	2.65	50	24	26	1.67	18
2	2.65	53	24.5	28.5	1.69	18.67
3	2.66	54	25	29	1.76	20
4	2.68	52	24	28	1.72	19.23

Table 3. Result of AAS of uncontaminated soil.

Heavy Metal	Cd (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Pb (mg/kg)
Sample A	6.08	0.21	1.65	0.21	0.03

Table 4. Result of AAS contaminated soil.

Heavy Metal	Cd (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Pb (mg/kg)
Sample A	9.08	0.45	2.75	0.50	0.06
Sample B	15.05	0.40	2.73	0.26	0.12
Sample C	13.03	0.33	2.50	0.19	0.10
Sample D	11.56	0.38	2.60	0.21	0.08

Assessment of pollution level of soil contaminated by fertilizer waste

➢ **Geo-Accumulation index (Igeo)**

- Developed by **G. Muller (1969)**
- Objective: as tool to summarized and interpret the raw analytical data in to a single Igeo Index value, which then specify the concentration/level of heavy metal in specific environment study.
- This heavy metal index focuses on determining the level of only **single heavy metal**.

Table 5. Classification of Geo-Accumulation Index (Muller, 1969).

Index class	Igeo Value	Level of contamination classification
0	Igeo<0	Uncontaminated
1	0<Igeo<1	Uncontaminated to moderately contaminated
2	1<Igeo<2	moderately contaminated
3	2<Igeo<3	Moderately to Heavy (strong) contaminated
4	3<Igeo<4	Heavy (strong) contaminated
5	4<Igeo<5	Heavy (strong) to extremely contaminated
6	Igeo≥5	Extremely contaminated

Geo-accumulation Index(Igeo) is calculated using the given equation

$$\mathbf{Igeo = \log_2 Cn/1.5*B_n}$$

where,
C_n=Concentration of the ith heavy metal in the X sample analyzed
NB: The value 1.5 is a factor used as constant for possible variation of the background data due to lithological variations.
B_n= Geochemical background value of the ith heavy metal in X sample analyzed.

Background value (B_n)

According to Muller (1969)

- The background value use is the concentration of heavy metals in contaminated soil during fertilizer industry waste.
- The concentration obtained during the study is.

Heavy Metals	Concentration
Cd	1.5
Mn	0.09
Zn	0.5
Cu	0.005
Pb	0.05

➢ **Geo-Accumulation index (Igeo) calculation:**
Determine the heavy metal concentration (Cn) in the soil.

Table 6. Undisturbed sites (Bn) Liao et. al. (2) (2004) etc.

	Sampling Sites				
Heavy Metal Studies	Undisturbed Site (Bn)	Sample Site A Cn	Sample Site B Cn	Sample Site C Cn	Sample Site D Cn
Cd	1.5	9.08	15.05	13.03	11.56
Mn	0.09	0.45	0.4	0.33	0.38
Zn	0.5	2.75	2.73	2.50	2.60
Cu	0.005	0.50	0.26	0.19	0.21
Pb	0.05	0.06	0.12	0.10	0.08

Table 7. Calculation for Sample 1(Cn)

Heavy Metal	Sample A Cn	Constant	Bn	Constant *Bn	Cn/ Constant* Bn	Log2 Cu/ Constant *Bn (Igeo Value)
Cd	9.08	1.5	1.5	2.25	4.035556	2.0127
Mn	0.45	1.5	0.09	0.135	3.33333	1.7369
Zn	2.75	1.5	0.5	0.75	3.66666	1.8744
Cu	0.50	1.5	0.005	0.0075	66.66667	6.0588
Pb	0.06	1.5	0.05	0.075	0.8	-0.3219

Table 8. Calculation for Sample 2(Cn)

Heavy Metal	Sample B Cn	Constant	Bn	Constant *Bn	Cn/ Constant *Bn	Log2 Cu/Constant*Bn (Igeo Value)
Cd	15.04	1.5	1.5	2.25	6.68444	2.7408
Mn	0.45	1.5	0.09	0.135	2.9629	1.5670
Zn	2.73	1.5	0.5	0.75	3.64	1.8639
Cu	0.26	1.5	0.005	0.0075	34.66667	5.1154
Pb	0.12	1.5	0.05	0.075	1.63	0.6780

Table 9. Calculation for Sample 3(Cn)

Heavy Metal	Sample C Cn	Constant	Bn	Constant *Bn	Cn/ Constant *Bn	Log2 Cu/Constant*Bn (Igeo Value)
Cd	13.0	1.5	1.5	2.25	5.7778	2.5305
Mn	0.33	1.5	0.09	0.135	2.4444	1.2895
Zn	2.50	1.5	0.5	0.75	3.3333	1.7369
Cu	0.19	1.5	0.005	0.0075	25.333	4.6629
Pb	0.10	1.5	0.05	0.075	1.3333	0.4150

Table 10. Calculation for Sample 4(Cn)

Heavy Metal	Sample D Cn	Constant	Bn	Constant* Bn	Cn/ Constant *Bn	Log2 Cu/Constant* Bn (Igeo Value)
Cd	11.56	1.5	1.5	2.25	5.137777778	2.361144491
Mn	0.38	1.5	0.09	0.135	2.814814815	1.493040011
Zn	2.6	1.5	0.5	0.75	3.466666667	1.793549123
Cu	0.21	1.5	0.005	0.0075	28.0000000	4.807354922
Pb	0.08	1.5	0.05	0.075	1.066666667	0.093109404

RESULTS AND DISCUSSION

Table 11. Result of Geo-Accumulation Index (Sample1)

Heavy Metal	Igeo Value	Igeo class	Sample A Geo-Accumulation Index (Pollution level)
Cd	2.0127	3	Moderately to Heavy (strongly) Contaminated
Mn	1.7369	2	Moderately Contaminated
Zn	1.8744	2	Moderately Contaminated
Cu	6.0588	6	Extremely contaminated
Pb	-0.3219	0	Uncontaminated

Table 12. Result of Geo-Accumulation Index (Sample2)

Heavy Metal	Igeo Value	Igeo class	Sample B Geo-Accumulation Index (Pollution level)
Cd	2.7408	3	Moderately to Heavy (strongly)Contaminated
Mn	1.5670	2	Moderately Contaminated
Zn	1.8639	2	Moderately Contaminated
Cu	5.1154	6	Extremely contaminated
Pb	0.6780	0	Uncontaminated

Table 13. Result of Geo-Accumulation Index (Sample3)

Heavy Metal	Igeo Value	Igeo class	Sample C Geo-Accumulation Index (Pollution level)
Cd	2.5305	3	Moderately to Heavy (strongly)Contaminated
Mn	1.2895	2	Moderately Contaminated
Zn	1.7369	2	Moderately Contaminated
Cu	4.6629	6	Heavily(strong) to extremely contaminated
Pb	0.4150	0	Uncontaminated

Table 14. Result of Geo-Accumulation Index (Sample 4)

Heavy Metal	Igeo Value	Igeo class	Sample D Geo-Accumulation Index (Pollution level)
Cd	2.361144491	3	Moderately to Heavy (strongly) Contaminated
Mn	1.493040011	2	Moderately Contaminated
Zn	1.793549123	2	Moderately Contaminated
Cu	4.807354922	6	Heavily(strong) to extremely contaminated
Pb	0.093109404	0	Uncontaminated

Above the table of result shows that in sample A, sample B, sample C and sample D of (Cn concentration is very high). It belongs to Igeo class 6 then soil is contaminated.

CONCLUSIONS

- This study concludes that the four samples of soil were collected from different location of fertilizer industry plant Gorakhpur have been determined by using AAS technique for five heavy metals (Cd, Mn, Zn, Cu and Pb) for evaluation to the high concentrations of five heavy metals in the soil.
- Organic fertilizer also enriches soil with potentially dangerous metals and other organic contaminants, in addition to inorganic fertilizer. However, because they improve the soil's nutritional status, moisture content, aeration, microbial diversity, and organic matter, organic fertilizer are more supportive of soil health.
- Moreover, fertilizers also add HMs to the soil that are taken up by the plants and enter the food chain where they affect human and animal lives.
- By the application of AAS test it was found that copper (Cu) is the major constituent in the tested soil as compared to other four metals as can be seen in the above result tables.

REFERENCES

1. V.V. Ranade, V.M. Bhandari, Industrial Wastewater Treatment, Recycling and Reuse, Elsevier, **2014**. DOI:10.1016/B978-0-08-099968-5.09986-4.
2. Van Breemen *et. al.* **1987**
3. Liao *et. al.*
4. McQuaker *et. el.* (**1979**)
5. A. Demir, A. Gunay, E. Debik, Ammonium removal from aqueous solution by ion-exchange using packed bed natural zeolite, *Water SA*, **2002**, 28, 329-336. DOI:10.4314/wsa.v28i3.4903.
6. M. Sarioglu, Removal of ammonium from municipal wastewater using natural Turkish (Dogantepe) zeolite, *Sep. Purif. Technol.* **2005**, 41, 1-11. DOI:10.1016/j.seppur.2004.03.008.
7. M.S. Çelik, B. Özdemir, M. Turan, I. Koyuncu, G. Atesok, H.. Sarikaya, Removal of ammonia by natural clay minerals using fixed and fluidised bed column reactors, *Water Sci. Technol. Water Supply.* **2001**, 1, 81-88.
8. L.G. Sorokhaibam, V.M. Bhandari, M.S. Salvi, S. Jain, S.D. Hadawale, V. V. Ranade, Development of Newer Adsorbents: Activated Carbons Derived from Carbonized Cassia fistula, Ind. *Eng. Chem. Res.* (**2015**) acs.iecr.5b02945. DOI:10.1021/acs.iecr.5b02945.
9. M. Aguilar, Nutrient removal and sludge production in the coagulation–flocculation process, *Water Res.*, **2002**, 36, 2910-2919. DOI:10.1016/S0043-1354(01)00508-5.
10. J. Kim, M.-J. Hwang, S.-J. Lee, W. Noh, J.M. Kwon, J.S. Choi, et al., Efficient recovery of nitrate and phosphate from wastewater by an amine-grafted adsorbent for cyanobacterial biomass production., *Bioresour. Technol.*, **2016**, 205, 269-73. DOI:10.1016/j.biortech.2016.01.055