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SLAGS AS AGRICULTURAL LIMES: REACTIVITY AND HEAVY METAL AND PHOSPHORUS BIO-AVAILABILITY

By

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DECLARATION

These studies have not been submitted in any form to another university and, except where acknowledged in the text, are the results of my own work.

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SUMMARY (ENGLISH)

Steel industry by-products (slags) are regularly used as agricultural limes on the South African Highveld where the soils are prone to natural and anthropogenic acidification. These materials are the products of a purification process aimed at extracting phosphorus and silica from iron (or related) ores. In the process several impurities such as heavy metals are incorporated into the slag. In certain quarters concern is being voiced about the environmental impact of these heavy metals.

Two pot experiments were conducted to test the heavy metal and phosphorus bioavailability from several commercial slags. Pot experiments differ from field experiments and heavy metal uptake is usually exaggerated in plants grown in pots. Furthermore, soil pH influences the mobility of heavy metals in soils. The limes were therefore applied to similar pH levels and the limes with high and low metal concentrations were compared.

The Resin Suspension Method (RH-value) was used as a reactivity parameter of the limes and a $Ca(OH)_2$ equilibration method was used to determine the lime requirement of the soils. Twelve limes were collected with the aid of the Registrar of Fertilisers and applied in the heavy metal experiment to obtain pH values of 5.8, 6.8, and 7.8. A further experiment to determine phosphorus availability was conducted using four slags to obtain pH values of 5.5, 6.0, and 6.5.

The heavy metal uptake was tested using spinach as test crop. The concentrations in the plants were high. There were no significant differences between the high and low metal containing limes. Spinach accumulates high concentrations of trace elements and therefore aggravates metal uptake compared to most other crops. The conclusion is that the use of slags poses little threat in the short term. Due to the nature of the experiments trial it is not possible to comment on the desirability of long-term slag use. Further research is required to determine the impact if soil heavy metal concentrations are increased and management practices lead to acidification.

The RH-value proved to be the most accurate reactivity indicator when compared to the Calcium Carbonate Equivalent (CCE) in HCl. Two different soil to solution ratios (1:1 and 1:2.5) in the $Ca(OH)_2$ determinations were used and compared with the pH at the end of the pot experiment. The 1:2.5 ratio combined with the RH-value gave pH predictions closest to the actual pH values. Although all the methods were relatively close to the actual values, the CCE HCl parameter led to wider variation in results. In limes with a small difference between the CCE HCl and RH values the predicted pH values also had a small difference. In the limes where the CCE HCl and RH values differed widely there was a corresponding large difference in predicted pH values.

In determining the P-availability from the slags it appeared as though the Si in the slags influenced the P-concentrations in the plants (spinach). In a soil with a low P-concentration the P-uptake was very low leading to the conclusion that the P was not available from the slags. This could also be because the P-levels in the slags were lower than reported by the producers and that the P desorbtion rate of the soil is very low. Due to the difficulty in differentiating between P reserves in the soil and P applied through the slags a different approach should be considered when testing P-availability from slags.

OPSOMMING (AFRIKAANS)

Staalverwerkingsnewe-produkte word gereëld gebruik as landboukalke op die Suid Afrikaanse Hoëveld waar gronde onderhewig is aan natuurlike en antropogeniese versuring. Hierdie materiale is die produkte van 'n suiweringsproses wat ten doel het om fosfor en silika van yster (of verwante) erts te ontrek. In die proses word verskeie onsuiwerhede soos swaar metale in die slak geïnkorporeer en het hierdie situasie gelei tot vrae oor die impak van dié metale op die omgewing en gesondheid.

Twee pot eksperimente is gedoen om die swaar metale en fosfor se bio-beskikbaareid vanaf die slakke te toets. Pot eksperimente verskil van veld eksperimente deurdat verhoogde opname van metale vanuit grond in potte gewoonlik plaasvind. Grond pH beïnvloed die mobiliteit van die swaar metale. Die slakke is dus tot soortgelyke pH teikens toegedien om die kalke met hoë en lae swaar metal konsentrasies te vergelyk.

Die Harssuspensiemetode (RH-waarde) is gebruik as 'n aanduiding van die kalke se reaktiwiteit en 'n $Ca(OH)_2$ ekwilibrasie metode is gebruik om die grond se kalkbehoefte te bepaal. Twaalf kalke is versamel met die hulp van personeel van die Registrateur van Misstowwe en is in die swaar metaal eksperiment toegedien om drie teiken pH waardes van 5.8, 6.8, en 7.8 te verkry. 'n Verdere eksperiment om fosfaat beskikbaarheid te bepaal is gedoen deurdat vier slakke toegedien is aan 'n verskillende grond tot pH teiken waardes van 5.5, 6.0, en 6.5.

Die swaarmetaal opname is bepaal deur die gebruik van spinasie as toetsgewas. Die vlakke was baie hoog in die plante. Daar was egter geen noemenswaardige verskil tussen die hoë metaal inhoud kalke en dié met laer vlakke nie. Spinasie akkumuleer hoë vlakke spoor elemente en vererger dus swaar metaal opname in vergeleke met ander gewasse. Die gevolgtrekking is dat die slakke min gevaar inhou in die korttermyn. Na aanleiding van die aard van die eksperimente is dit nie moontlik om kommentaar te lewer op die wenslikheid van die langtermyn gebruik van slakke nie. Verdere navorsing is nodig om die impak te bepaal wanneer swaar metaal konsentrasies verhoog word en bestuurspraktyke lei tot versuring van die grond.

Die RH-waarde is bewys as die mees akkurate aanduiding van reaktiwiteit indien vergelyk met die Kalsium Karbonaat Ekwivalent (KKE) in HCl. Twee verskillende grond-tot-oplossing verhoudings (1:1 and 1:2.5) in die $Ca(OH)_2$ bepalings was gebruik en is vergeyk met die pH waardes aan die einde van die eksperiment. Die 1:2.5 verhouding gekombineer met die RH-waarde het pH voorspelling gelewer wat die naaste aan die teiken waardes was. Alhoewel al die metodes waardes gelewer het wat redelik naby aan die werklike waardes was het die KKE in HCl parameter tot wyer variasie gelei. In kalke waar daar 'n klein verskil was tussen die KKE in HCl en RH waardes was daar 'n klein verskil in die pH waardes verkry. In kalke met 'n groot verskil tussen die KKE in HCl en die RH waardes was daar 'n ooreenstemmende groot verskil tussen die voorspelde pH waardes verkry.

In die bepaling van die P-beskikbaarheid van die slakke wil dit voorkom asof die Si in die slakke die P-konsentrasies in die plante (spinasie) beïnvloed het. In 'n grond met 'n lae P-konsentrasie was die P-opname laag wat lei tot die gevolgtrekking dat die P nie beskikbaar was vanuit die slakke nie. Dit kan toegeskryf word daaraan dat die P-vlakke in die slakke laer is as wat weergegee is deur die produseerders van die slakke en dat die P desorpsie tempo van die grond baie laag is. Na aanleiding van die onvermoë om te onderskei tussen P reserwes in die grond en die P toegedien deur die slakke sal 'n ander benadering oorweeg moet word wanneer P-beskikbaarheid van slakke bepaal word.

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