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The manuscript will be checked by Editors and then sent to the Reviewers. You will be informed by email about any further decisions on this article.

Thank you for submitting your work to our journal.

With kind regards,

Professor Hanna Radecka Editor - in - Chief Polish Journal of Environmental Studies

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sudarningsin@uim.ac.id		Table 1. – the same number of decimals should be maintained.
C Inhortant 509	Polish Jour In 24/02/22 20.23	rigures 1 – 3 – These are the same data as in Table 1, remove these Figures – they are incorrect, as far as Lunderstand there isn't any connection between flex point 0" in Site A and B so it is
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Thank you very much for sending the revised manuscript. But, unfortunately the docx document with detailed answer for each Reviewer's comments cannot be open. Thus, please send again the fully revised manuscript that has all the changes highlighted in red colour, along with high-quality figures and detailed answers to all the Reviewer comments in COC or PDF format.

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Thank you for submitting your work to our Journal and fruitful co-operation.

With kind regards,

Prof. Hanna Radecka Editor in Chief Polish Journal of Environmental Studies www.pioes.com

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Dear Prof.Hanna Radecka Enclosed please find the revised manuscript and auhor's respon form in PDF format. See More Yours sincerely, Sudarningsih

Editor in-chief prof. Hanna Radecka Polish Journal of Environmental Studies www.pjoes.com <<u>http://www.pjoes.com/</u>>

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#### Sudar Ningsih

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To: officehard pjoes.home.pl

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Sincerely yours

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Polish Journal of Environmental Studies New message (PJOES-00324-2022-03) To: Sudar Ningsih.

Reply-To: office@pjoes.com

Dear Dr. Sudarningsih Sudarningsih,

Hanna Radecka sent new message regarding the article Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia (PJOES-00324-2022-03):

#### Dear Sudarningsih,

I have asked our techical team in order to help you.

Best regards Hanna Radecka

#### Reply:

https://www.editorialsvstem.com/pioes/article/298037/view/#messages

Editorial Office of Polish Journal of Environmental Studies

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Dear Dr. Sudarningsih.

Please use your account <a href="mailto:sudarningsih@ulm.ac.id">sudarningsih@ulm.ac.id</a> to login here:

https://www.editorialsystem.com/pioes/dashboard/

Then go to https://www.editorialsystem.com/pjoes/author/sent/?onlyAwaiting=true

and click Enter the revised article option:

#### Manuscripts submitted to editors (1)

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Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia	Sent to revise 2022-06-20	Enter the revised article     Messages (2)
	Deadline 2022-07-21	

With kind regards, Bartek Stefaniak

Pierwotna wiadomość ------Od: Polish Journal of Environmental Studies <kontakt@editorialsystem.com> Do: Hanna Radecka <u>soffices.com></u> Data: 24.06.2022 04:04 Temat: New message (PJOES-00324-2022-02)

Dear Prof. Hanna Radecka,

Sudarningsih Sudarningsih sent new message regarding the article Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia (PJOES-00324-2022-

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Pierwotna wiadomość --Od: Polish Journal of Environmental Studies <kontakt@editorialsystem.com> Do: Hanna Radecka <office@pjoes.com> Data: 24.06.2022 04:04 Temat: New message (PJOES-00324-2022-02) Dear Prof. Hanna Radecka, Sudarningsih Sudarningsih sent new message regarding the article Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia (PJOES-00324-2022-02): Dear editor, I can't find a botton in PJOES on-line system that I can click to submit my revised manuscript and auhor's respon form. Sincerely, Sudarningsih Reply: https://www.editorialsystem.com/editor/pjoes/article/294401/view/#messa aes Editorial Office of Polish Journal of Environmental Studies Editor in-chief prof. Hanna Radecka Polish Journal of Environmental Studies www.pjoes.com Searching "Inbox – sudarningsi... 🕂 🗐 🛛 🖸 🗊 🐨 🖧 🖧 🟲 🗸 🔌 >> Q PIOES 0 All Re Polish Journal of Environmental Studies Dear Dr. Sudarningsih Sudarningsih, □Inbox -...ulm.ac.id 24 June 2022 22.25 All Mailboxes New revision received by Editorial Office (PJOES-00324-2022-03) Your manuscript: Assessment of S. To: Sudar Ningsih, Polish Jour... In... 24/06/22 22.25 ✓ ♀ All Inboxes Reply-To: office@pioes.com 🖂 sudarningsih@... 1,132 🖂 sudarningsihun... 1.470 Dear Dr. Sudarningsih Sudarningsih, V 🖪 All Sent Thank you for the revision of the manuscript: Assessment of Soil Contamination by Heavy Metals: A Bartosz Ste... In... 24/06/22 16.19 🛷 sudarningsih@ulm... 13 Case of Vegetable Production Center in Banjarbaru Region, Indonesia. The following number has been assigned to it: PJOES-00324-2022-03. Re: Fwd: New message (PJOES-... @ 🛷 sudarningsihunla... 23 Dear Dr. Sudarningsih, Please use > 🕒 All Drafts 30 P Flagged 12 your account sudarningsih@ulm.a... The manuscript will be rated once again by the Editors and then sent to the Reviewers. Polish Jour... In... 24/06/22 16.09 You will be informed by email about any further decisions on this article. Smart Mailboxes New message (PJOES-00324-20... Dear Dr. Sudarningsih Sudarningsih, With kind regards, Hanna Radecka sent new message... 🎁 Trash Professor Hanna Radecka 🛅 Pesan yang Dipulihkan (... \* officehard... In... 23/06/22 16.10 Editor - in - Chief 🛅 Pesan yang Dipulihkan (s... Re: Revised manuscript and auth... Polish Journal of Environmental Studies www.pjoes.com Dear Sudar Ningsih, Your sudarningsih01@ulm.ac.id manuscript PJOES 00324-2022 h... 🛅 Pesan yang Dipulihkan (s... Editorial System is available here: https://www.editorialsystem.com/pioes/ Recovered Messages (su... Polish Jour... In... 20/06/22 17.31 Recovered Messages (su... Decision on manuscript PJOES-0... June 20, 2022 PJOES-00324-2022-02 Assessm... 🗎 Important 509 🖂 Inbox 1,132 Polish Jour... In... 07/06/22 22.28 New revision received by Editorial... Drafts 8 13 Dear Dr. Sudarningsih Sudarningsih, ┥ Sent Thank you for the revision of the m... 27 👿 Junk Polish Jour... In... 24/05/22 02.52 🎁 Trash Decision on manuscript PJOES-0... Archive 2,398 May 23, 2022 Moved 2019-01-29... 57 PJOES-00324-2022-01 Assessme...

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Reply-To: office@pjoes.com

#### July 25, 2022 PJOES-00324-2022-03

Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia

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Dear Dr. Sudarningsih Sudarningsih,

I am pleased to inform you that your manuscript, entitled: Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia, might be accepted for publication in our journal, pending changes suggested by reviewers (see below).

Please revise your manuscript strictly according to the attached Reviewers' comments as well as Editor's remarks. Your manuscript won't be taken into consideration without the revisions made according to the recommendations.

Please, check all Editor's remarks when revising your manuscript: - R e f e r e n c e s should be indicated in the text by consecutive numbers and the full references should be listed in the same order at the end of the article according to Journal way

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 Manuscript should be divided into the sections: Abstract, Keywords, Introduction, Material and Methods ( could be omitted in Reviews), Results and Discussion, Conclusions, Acknowledgements, References

Please, provide the following items: 1) copy of the fully revised manuscript that has all the changes highlighted in red colour, along with high-quality figures. Each figure prepared in colour will be charged 60 EURO 2) answers to all the Reviewer comments

Authors of our journal are requested to prepare a revised version of their manuscript as soon as possible. This may ensure fast publication if an article is finally accepted.

Thank you for submitting your work to our Journal and fruitful co-operation.

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Re: Decision on manuscript PJOES-00324-2022-04

Sudarningsih Sudarningsih

29 August 2022 17.22

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Best Regard Sudarningsih Sudarningsih

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Thank you very much for selecting of our Journal and fruitful co-operation.

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With kind regards,

Professor Hanna Radecka Editor - in - Chief Polish Journal of Environmental Studies www.pioes.com

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I am pleased to inform you that your manuscript PJOES-00324-2022-04, entitled Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia is considering for publication in Polish Journal of Environmental Studies, issue: Manuscripts accepted.

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With kind regards,

Professor Hanna Radecka Editor – in – Chief Polish Journal of Environmental Studies www.pjoes.com

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Dear Dr. Sudarningsih Sudarningsih,

We would like to inform you that manuscript Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia (PJOES-00324-2022-04) has been indexed in CrossRef.

Assigned DOI: 10.15244/pjoes/153074

Link: https://doi.org/10.15244/pjoes/153074

Article view: https://www.editorialsystem.com/pjoes/article/302823/view/

Please, notice that the number of pages will be assigned after the printing of hard copy. We would like to thank you for selecting our journal and for the fruitful co-operation.

Looking forward to your next submission.

Editorial Office of Polish Journal of Environmental Studies

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## Authors:

Sudarningsih Sudarningsih, Fahruddin Fahruddin, Muhammad Lailiyanto, Alif Noer, Sadang Husain, Simon Siregar, Sri Wahyono

## **Decision letter:**

May 23, 2022 PJOES-00324-2022-01 Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia

Dear Dr. Sudarningsih Sudarningsih,

I am pleased to inform you that your manuscript, entitled: Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia, might be accepted for publication in our journal, pending changes suggested by reviewers (see below).

Please revise your manuscript strictly according to the attached Reviewers' comments as well as Editor's remarks. Your manuscript won't be taken into consideration without the revisions made according to the recommendations.

Please, check all Editor's remarks when revising your manuscript:

- R e f e r e n c e s should be indicated in the text by consecutive numbers and the full references should be listed in the same order at the end of the article according to Journal way

- In references all authors name must be included

- E-mail address of Corresponding Author must be provided

- Manuscript should be divided into the sections: Abstract, Keywords, Introduction, Material and Methods ( could be omitted in Reviews), Results and Discussion, Conclusions, Acknowledgements, References

Please, provide the following items:

1) copy of the fully revised manuscript that has all the changes highlighted in red colour, along with high–quality figures. Each figure prepared in colour will be charged 60 EURO

2) answers to all the Reviewer comments

Authors of our journal are requested to prepare a revised version of their manuscript as soon as possible. This may ensure fast publication if an article is finally accepted.

Thank you for submitting your work to our Journal and fruitful co-operation.

With kind regards,

Dorota Radecka PhD Executive editor Polish Journal of Environmental Studies www.pjoes.com



## Review 1:

How important do you consider the results reported? important

Do the data obtained by experiment or calculation verify the conclusions?  $\ensuremath{\mathsf{Yes}}$ 

Is the length of the manuscript appropriate to its contents? Yes

**The paper should be published as:** Original full paper

**Detailed description:** 

**English-Linguistic correctness: grammar, structure, vocabulary** Good

Abstract

Good

Introduction Good

Figures ( are all necessary ?) Good

Tables (are all necessary ?) Good

References Good

Authors used only 12 samples which celarly is not statiscally significant. Some justification should be given on this,

### **Review 2:**

How important do you consider the results reported? less important

**Do the data obtained by experiment or calculation verify the conclusions?** Yes



Is the length of the manuscript appropriate to its contents?  $\ensuremath{\mathsf{Yes}}$ 

**The paper should be published as:** Original full paper

## **Detailed description:**

**English-Linguistic correctness: grammar, structure, vocabulary** Fair

## Abstract

Fair

Introduction Fair

# Figures ( are all necessary ?)

Not acceptable

Tables (are all necessary ?) Fair

References

Fair

The manuscript should be corrected by removing unnecessary repetitions of data (the same data in Tables and in Figures) and detailed description of sites and sampling points should be added.

Summary, line 26 - why Zn is two times Map with locations of sampling points needed In how many repetitions analyses were conducted? Line 107- Why division into site A and B was performed – what was the difference between thes two sites? Again map with marked Site A and B needed. Pleaese explain shortly this Rahman's method Table 1. – the same number of decimals should be maintained. Figures 1 – 3 – These are the same data as in Table 1, remove these Figures – they are incorrect, as far as I understand there isn't any conection between f.ex. point "0" in Site A and B, so it is inappropriate to show them as one bar. What is the difference between Table 2 and Figure 4? They both show Igeo but the results are different. And again this is unecessary repetitions.

I suggest to expand description of both sites and sampling points and try to explain where such big differences in specific locations come from (f.ex. in site A1). Detailed



description of the way of taking samples is needed.



# FIRST REVISION

#### Author's Respond Form

Manuscript ID	PJOES-00324-2022-01
Title	Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia
Authors	Sudarningsih Sudarningsih *, Fahruddin Fahruddin, Muhammad Lailiyanto, Alif Antasari Noer, Sadang Husain, Simon Sadok Siregar, Sri Cahyo
	Wahyono, Ichsan Ridwan
Submission date	05 March 2022
Revision date	26 May 2022
Reviewer	2

Editor's Evaluation	Details of Author's Respond	Modification
Editor's Comments	Author's Respond	
R e f e r e n c e s should be indicated in the text by consecutive numbers and the full references should be listed in the same order at the end of the article according to Journal way	This has been revised accordingly	
In references all authors name must be included	This has been revised accordingly	
E-mail address of Corresponding Author must be provided	This has been revised accordingly	
Manuscript should be divided into the sections: Abstract, Keywords, Introduction, Material and Methods (could be omitted in Reviews), Results and Discussion, Conclusions, Acknowledgements, References	This has been revised accordingly	
Answers to all the Reviewer comments	This has been revised accordingly	

Reviewers' Evaluation	Details of Author's Respond	Modification			
Reviewer-1 Comments	Author's Respond				
Authors used only 12 samples which clearly is not statically significant. Some justification	This has been revised accordingly	See lines 105-108: Twelve agriculture soil samples were taken from two different area (Site A and			
should be given on this.		site B) (Fig.1). Site A in Dahor Formation and site B in alluvial soil [20]. In general, agricultural soils in these two areas tend to be homogeneous with the chemical composition of the soil having low variability [19].			

Reviewers' Evaluation	Details of Author's Respond	Modification				
Reviewer-2 Comments	Author's Respond					
The manuscript should be corrected by removing unnecessary repetitions of data (the same data in Tables and in Figures) and detailed description of sites and sampling points should be added.	This has been revised accordingly					
Summary, line 26 - why Zn is two times	This has been revised accordingly	See line 26: The average concentration of heavy metals in the sampling area A is Fe>Zn>Mn>Cu>Hg, and the area B is Fe>Mn>Zn>Cu>Hg.				
Map with locations of sampling points needed	We have added map with locations of sampling points.	See line 482: Figure 1:				
		Figure 1. The sampling site of agriculture soil from vegetable production center in Banjarbaru Region.				

In how many repetitions analyses were conducted?	This has been revised accordingly	We have r	emoved the	e figures.					
Line 107- Why division into site A and B was performed – what was the difference between thes two sites? Again map with marked Site A and B needed. Pleaese explain shortly this Rahman's method	This has been revised accordingly	See line 48 Figure 1. 7 in Banjarb See line 10 These sam methods. soil surfac in distance The samp sampler n sample wa	32: The samplir aru Region 98-113: uples were c Approxima e layer (15- e from one le taken is naterial. Sa as transferro	ng site of a collected u tely 250–3 -20 cm) us sampling in the cen mples are ed to a pre	sing the sar 300 g of agr ing a stainle point to an ter to avoid checked for eviously cle	soil from ve npling proc icultural so ess steel gra other in on d contact w or possible aned plastic	egetable pro edure based il were colle b sampler. e location is rith the insi- contaminat c container	duction cen d on Rahma ected from The differen s about 100 de of the g tion. Then [21].	nter an's the nce m. rab the
Table 1. – the same number of decimals should be maintained.	This has been revised accordingly	See line 41 Table 1:	.8:						
			Fe	Zn	Mn	Cu	Hg	ν (x 10∗	]
		Sample	(mg/kg)	(mg/k g)	(mg/kg)	(mg/kg)	(mg/kg)	m <sup>3</sup> kg <sup>3</sup> )	
		Sampling	g Area A						]
		A0	28,600.0 0	156.00	112.00	49.00	0.12	136.50	
		A1	28,100.0 0	124.00	161.00	147.00	0.12	135.60	
		A2	27,300.0 0	77.00	60.00	70.00	0.08	100.10	
		A3	26,900.0 0	57.00	52.00	70.00	0.11	135.60	
		A4	31,800.0 0	65.00	70.00	89.00	0.09	47.30	
		A5	30,400.0 0	71.00	81.00	91.00	0.11	44.80	
		Min	26,900.0 0	57.00	52.00	49.00	0.08	44.80	
		Max	31,800.0 0	156.00	161.00	147.00	0.12	136.50	
		Mean	28,850.0 0	91.67	89.33	86.00	0.10	100.00	
		SD	1,893.94	39.00	41.00	34.00	0.01	44.03	ļ
		Sampling	g Area B						

		B0	2,500.00	20.00	38.00	7.00	0.01	23.30	
		B1	1,500.00	21.00	23.00	7.00	0.04	21.00	
		B2	1,000.00	65.00	15.00	5.00	0.01	24.30	
		B3	8,200.00	14.00	68.00	12.00	0.01	1.10	
		B4	4,800.00	14.00	39.00	9.00	0.01	1.90	1
		B5	1,000.00	20.00	15.00	5.00	0.01	1.60	
		Min	1,000.00	14.00	15.00	5.00	0.01	1.10	1
		Max	8,200.00	65.00	68.00	12.00	0.04	24.30	
		Mean	3,166.67	25.67	33.00	7.50	0.01	12.20	-
		SD	2,850.03	19.52	20.17	2.66	0.01	11.74	
		Baselin e	4.72	95.00	850.00	45.00	0.40	-	
Figures 1 – 3 – These are the same data as in Table 1, remove these Figures – they are incorrect, as far as I understand there isn't any connection between f.ex. point "0" in Site A and B, so it is inappropriate to show them as one bar. What is the difference between Table 2 and	We have removed the figures. We have removed Figure 4.								
Figure 4? They both show Igeo but the results are different. And again this is unnecessary repetitions.									
I suggest to expand description of both sites and sampling points and try to explain where such big differences in specific locations come from (f.ex. in site A1).	This has been revised accordingly	See line 181-185: At site A, the content of Mn and Cu at point A1 is higher than at other points which are suspected come from fertilizers and pesticides [36], also from traffic waste [28, 29], as well as Zn. This is known based on the location of point A1 which is closest to the highway. In addition, the high content of Mn at point A1 is thought to also originate from the post-harvest processing of agricultural land [38].							
Description of the way of taking samples is needed.	This has been revised accordingly	See line 108-113: These samples were collected using the sampling procedure based on Rahman's methods. Approximately 250–300 g of agricultural soil were collected from the soil surface layer (15–20 cm) using a stainless steel grab sampler. The difference in distance from one sampling point to another in one location is about 100 m. The sample taken is in the center to avoid contact with the inside of the grab sampler material. Samples are checked for possible contamination. Then the sample was transferred to a previously cleaned plastic container [21].							

# Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia

#### Keywords

contamination factor, geoaccumulation index, pollution load index, contamination degree

#### Abstract

Landasan Ulin is a center for vegetable production, and it has an important role in producing vegetables for the city of Banjarbaru. Agricultural soil in this study was assessed for heavy metal contamination using the geoaccumulation index (Igeo), contamination factor (Cfi), the degree of contamination (Cd), the degree of modified contamination (mCd), and the Pollution Load Index (PLI) as well as magnetic susceptibility. Samples were collected from topsoil and analyzed using magnetic susceptibility and Atomic Absorption Spectrophotometer (AAS). The average concentration of heavy metals in the sampling area A is Fe>Zn>Mn>Cu>Hg, and the area B is Fe>Mn>Zn>Cu>Hg. Magnetic susceptibility values in area A is higher than in area B and the value of magnetic susceptibility can be used as a proxy for monitoring heavy metal concentrations, especially Zn in this area. Zn and Cu exceeded the threshold set by the Indonesian Standards Institute. Igeo results show that the research area is moderately contaminated with Cu, Zn, and Hg. According to Cfi, the soil was classified as low contaminated with Fe, Zn, Cu, Mn, and Hg, as well as Cd and mCd. The PLI results show that in both area, drastic corrective action is not required.

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**Explanation letter** This is s file of author's respon form.



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22	22	Abstract:
23	23	
24	24	Landasan Ulin is a center for vegetable production, and it has an important role in producing vegetables
25	25	for the city of Banjarbaru. Agricultural soil in this study was assessed for heavy metal contamination
26	26	using the geoaccumulation index (Igeo), contamination factor $(C_f^{1})$ , the degree of contamination (Cd),
	27	the degree of modified contamination (mCd), and the Pollution Load Index (PLI) as well as magnetic
27	28	susceptibility. Samples were collected from topsoil and analyzed using magnetic susceptibility and
28	29	Atomic Absorption Spectrophotometer (AAS). The average concentration of heavy metals in the
29	30	sampling area A is Fe>Zn>Mn>Cu>Hg, and the area B is Fe>Mn>Zn>Cu>Hg. Magnetic susceptibility
30	31	values in area A is higher than in area B and the value of magnetic susceptibility can be used as a proxy
32	32 22	for monitoring neavy metal concentrations, especially Zn in this area. Zn and Cu exceeded the threshold set by the Indenssion Standards Institute. I apply results show that the research area is moderately
02	22	set by the indonesian Standards institute. Igeo results show that the research area is moderately
33	34	contaminated with Cu, Zn, and Hg. According to $C_f$ , the soil was classified as low contaminated with
	35	Fe, Zn, Cu, Mn, and Hg, as well as Cd and mCd. The PLI results show that in both area, drastic corrective
34	36	action is not required.
35	37	
36	38	Keywords: geoaccumulation index; contamination factor; contamination degree; pollution load
37	39	index
38	40	



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#### 40 41 Introduction

Heavy metal contamination of agricultural soil due to chemical fertilizers and pesticides is a serious ecological problem today [1, 2]. In agricultural soil, the continuous use of manure and chemical fertilizers for a long time will result in higher heavy metal content [3, 4]. Some heavy metals are needed for the growth of certain plants [5], but some of them for humans can be toxic. When these heavy metals are absorbed and accumulated by plants and then consumed by humans, this will pose a risk to the human body [6]. 

Some heavy metals have been found in agricultural land in several areas in Indonesia, such as Pb found in soil from 168 locations with different land use and traffic conditions in Yogyakarta, Indonesia [7]. In Semarang, Indonesia, the paddy field contains heavy metals Pb, Cd, and Cu [8]. In agricultural land in Karawang, Pb and Cd were found with concentrations exceeding 1.0 ppm [9]. Meanwhile, in agricultural soils in Bangladesh for the dry season, heavy metals were found with concentrations of As>Fe>Hg>Mn>Zn>Cu>Cr>Ni>Pb>Cd and in the rainy season As>Fe>Mn>Zn>Hg>Cu>Ni>Cr>Pb>Cd [10]. In paddy soils at Hunan Province, China, there was founded heavy metals (Cd, Cr, As, Ni, Mn, Pb, and Hg) in three different locations [11]. 

The presence of magnetic minerals in the soil can come from weathering of the parent rock (lithogenic origin) and can also come from human activities (anthropogenic). Magnetic minerals that are commonly found in soil are hematite and magnetite. Their presence is in the form of solid waste which can act as the main absorber of pollutants such as heavy metals in the soil. Their presence in the soil will affect the value of the magnetic susceptibility of the soil. The use of magnetic susceptibility has been widely used in various soil science studies, such as soil morphology and genesis as well as tools for mapping the distribution of environmental pollutants [12]. Magnetic susceptibility measurement has been considered as a fast and cheapest monitoring tool for determining the spatial distribution of heavy metal presence in soil and can be used as a proxy for chemical methods [13]. Research using the method of environmental magnetism in Indonesia is still few in number. Several studies were conducted to examine the river and lake environment [14–17] Therefore, this study is very important. 

Landasan Ulin is a vegetable center production in Banjarbaru City, South Kalimantan, Indonesia. Agricultural activities in this area are carried out by farmers traditionally [18]. Meanwhile, agricultural land has the potential to experience heavy metal pollution, and studies on heavy metal pollution in agriculture in this area are still rarely carried out. Therefore, it is very important to conduct this research to determine the current status of the presence of these heavy metals on the surface of agricultural soil. This will be of benefit to ameliorate the impacted environmental problems further, and to adopt mitigation strategies in the future. This study aims to investigate the level of contamination of various heavy metals (Fe, Mn, Cu, Zn, Hg) in agricultural land located in Landasan Ulin, South Kalimantan, Indonesia, using different indices such as geoaccumulation index, pollution factor, degree of pollution, and the pollution load index. The correlation between heavy metal contamination and magnetic susceptibility is also investigated in this study. These results can be used as an alternative method in determining 



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81 81 heavy metal contamination in agricultural areas. This approach will help monitor the presence
82 82 of heavy metals in agricultural soils and soil remediation. Monitoring for polluted areas is
83 83 crucial, and it is beneficial for the sustainability of pollution management and control in the
84 84 future.

- 85 85 Materials and Methods
- 86 86 Study Area

87 87 Sampling and Measurements

88 88 Index of Geoaccumulation, Contamination Factor ( $C_{f}^{i}$ ), Degree of Contamination (Cd) and

89 89 *Pollution Load Index (PLI)* 

Landasan Ulin, South Kalimantan Province, Indonesia, has a 92.42 km2 area, consisting of mountains and hills in the north and east, and lowlands to the west, while the south has alluvium and swamp areas. Landasan Ulin is about 40 km from the provincial capital, Banjarmasin. Landasan Ulin is a vegetable production area in South Kalimantan. The cultivated vegetables from the area include mustard greens, kale, spinach, eggplant, lettuce, long beans, peanuts, and scallions. One of the efforts to increase the yield and quality of vegetables is through fertilization. Both organic and inorganic fertilizers are applied. The used dose of organic fertilizer was 485 kg, or an average of 16.17 kg/farmer, while the inorganic fertilizer was 556 kg, or an average of 18.53 kg/farmer. Nitrogen (N) fertilizer is critical for the growth of vegetables. The crops are never separated from the disturbance of weeds and pests. Theoretically, weeds are bothering vegetable growth because they are competitive in many ways, especially in getting water, sunlight, and nutrients. Weeds also, in some cases, become the source of the disease that often becomes a significant threat to the corps. To manage the growth of weeds, farmers do the chemical control of weeds regularly by using Gramoxon. About 400 liters is enough to kill weeds on an average of 13.33 liters/respondent. Removing the weeds can also be done manually by using physical measures or machinery. Meanwhile, in overcoming pests and diseases in North Landasan Ulin Village, the farmers used Ampligo, one of the pesticide brands. It is sprayed regularly with a dose that ranges from 20 liters or an average of 0.67 liters/farmer to kill/destroy pests that stick around the leaves and stems of mustard greens [19]. 

Twelve agriculture soil samples were taken from two different area (Site A and site B) (Fig.1). In general, agricultural soils in these two areas tend to be homogeneous, with the chemical composition of the soil having low variability [19]. But geologically, these two areas are in two different formations. Site A is in the Dahor Formation and Site B is in alluvial soil [20]. That is why this research is divided into two different research areas. These samples were collected using the sampling procedure based on Rahman's methods. Approximately 250–300 g of agricultural soil were collected from the soil surface layer (15-20 cm) using a stainless steel grab sampler. The difference in distance from one sampling point to another in one 



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location is about 100 m. The sample taken is in the center to avoid contact with the inside of the grab sampler material. Samples are checked for possible contamination. Then the sample was transferred to a previously cleaned plastic container [21]. In the laboratory, the soil sample was dried by aerating at room temperature. The dry soil samples were sieved using a 325 mesh-size sieve (44 µm in diameter) to obtain homogeneous soil particles. 2–3 g dry soil samples were digested in about 15 mL of aqua-regia (HCL: HNO3 = 3:1) for about 4–5 hours on a hotplate set to 110 °C. The materials were then diluted to 50 mL in a 100 mL Pyrex glass beaker with distilled water. In the laboratory of the Indonesian Geological Survey in Bandung, Indonesia, by AA280FS Atomic Absorption Spectrometer (AAS) (Variant Inc. Palo Alto, USA), the solution was filtered, and the filtrates were examined. The working standard solutions for each metal were prepared before every analysis. An air acetylene flame AAS was used to measure Fe, Zn, Cu, Pb, and Mn concentrations, with As determined by hydride vapor generation AAS. Magnetic susceptibility measurement was carried out in the following way, the dried soil sample was put into a cylindrical plastic holder with a diameter of 25.4 mm and a height of 22 then measured using a Susceptibilitymeter (Bartington Instrument Ltd., Oxford, UK). Each sample was measured with three repetitions. The magnetic susceptibility value used is the average value of the results of this measurement [13]. 

To analyze the level of heavy metal pollution in an area, more than one pollution index analysis is needed (3, 21, 36, 37), so in this study 5 pollution indices were used, namely the geoaccumulation index (Igeo), contamination factor (Cfi), the degree of contamination (Cd), the degree of modified contamination (mCd), and the Pollution Load Index (PLI). The five pollution indices are expected to provide more accurate information on the level of pollution in this research area. 

141 Müller's geoaccumulation index (Igeo) [22], which was originally established to measure
143 142 contamination of sedimentary bottoms, may now be used to assess soil contamination. It's
144 143 <u>calculated using equation (1) as follows:</u>

144 
$$I_{\text{geo}} = \log_2 \frac{C_n}{1.5B_n} (1)$$

146145Cn is the element's observed concentration in the pelitic sedimentary fraction (<2 m), and Bn is</th>147146the geochemical background value based on argillaceous sedimentary fossils (shale mean).  $C_f^i$ 148147and  $C_d$  are indices that can be used to assess soil contamination which consists of four classes149148[23]. Equation (2) was utilized in the following way:

150 149 
$$C_{f}^{i} = \frac{C_{0}^{i}}{C_{r}^{i}}(2)$$

151 150  $C_0^{i}$  is the pre-industrial concentration of the specific metal, and  $C_n^{i}$  is the mean content of metals 152 151 from at least five sampling sites. As a result, the computed  $C_d$  is defined as the amount of  $C_f^{i}$ 153 152 determined by Hakanson for the polluting species [23]. The following is the equation used to 154 153 calculate  $C_d$ 

155 154  $C_d = \sum_{i=1}^n C_f^i$  (3)



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C<sub>d</sub> is intended to measure the overall level of contamination in the surface layer at a particular sampling site. In this study, we applied a factor modification as applied by Krzysztof [24]. Abrahim [25] proposes the following modified and generalized version of the Hakanson equation [23] for estimating the total degree of contamination at a sample or coring location. Equation 4 is a modified equation for the general approach to calculating contamination levels.  $mC_{\rm d} = \frac{\sum_{i=1}^{i=n} C_f^i}{n} (4)$ 

Where n denotes the number of elements to be examined and the contamination factor is abbreviated as C<sub>f</sub><sup>i</sup>. Using this formula to compute mC<sub>d</sub> allows metals to be incorporated into studies with no upper limit. To identify pollution, Tomlinson created the pollutant load index (PLI) [26]. This index allows for comparisons of pollution levels between sites and across time. The PLI was calculated as a concentration factor for each heavy metal in relation to the soil background value. The background for the heavy metal in this investigation was the average world concentration of the examined metal reported for shale [27]. PLI can assess the level of metal contamination and the actions that must be taken. The formulas used are in the form of equations (5).

172 170 PLI = 
$$n\sqrt{C_{f1} \times C_{f2} \times ... \times C_{fn}}$$
 (5)

- **Results and Discussion**
- Heavy metal Content and Magnetic susceptibility
- Soil Pollution Degree
- *Correlation Between Heavy Metal Content and Magnetic Susceptibility*

Table 1 shows the average concentrations of a number of metals in the agricultural soils of the study area. The average Fe, Zn, Mn, Cu, and Hg concentrations in study area A were 28,850.00, 91.67, 89.33, 86.00, and 0.10 mg/kg. The average amounts of Fe, Zn, Mn, Cu, and Hg in B were 3,166.00, 25.67, 33.00, 7.50, and 0.01 mg/kg, respectively. Metal trends in research area A are Fe>Zn>Mn>Cu>Hg. Meanwhile, the trends of metals according to the average concentration in study area B is: Fe>Mn>Zn>Cu>Hg. Due to the agronomic practice, the concentration of heavy metals in study area B was various. Meanwhile, metal concentration trends in study area B are as follows: Fe>Mn>Zn>Cu>Hg. The concentration of heavy metals in study area B varied due to agronomic practices. The low heavy metal concentration in the soil can be attributed to the constant elimination of heavy metals by vegetables grown in the designated regions [21]. Table 1 also includes the magnetic susceptibility values of the samples from areas A and B. In general, the magnetic susceptibility values of area A  $(100.0 \times 10^{-8} \text{ m}^3 \text{kg}^-)$ <sup>1</sup>) were 9 times greater than those of area B ( $12.2 \times 10^{-8} \text{ m}^3\text{kg}^{-1}$ ). Magnetic susceptibility of sampling area A ranges from 44.8 to  $136.5 \times 10^{-8} \text{ m}^3 \text{kg}^{-1}$ , while magnetic susceptibility of sampling area B ranges from 1.1 to  $24.3 \times 10^{-8} \text{ m}^3\text{kg}^{-1}$ . Agricultural practices, such as the use of magnetic minerals such as Fe in fertilizers and pesticides, can increase the magnetic mineral content of agricultural soil. Magnetic minerals in agricultural soil can also be found in 



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<sup>196</sup> 193 household waste. As is well known, the research site, area A, is located very close to
<sup>197</sup> 194 settlements, whereas area B is located far from settlements. Household waste contains
<sup>198</sup> 195 anthropogenic magnetic minerals, which can raise the magnetic susceptibility value [28].

199196The content of Mn and Cu at point A1 in area A is higher than at other points, which are200197suspected to be from fertilizers and pesticides [36], as well as traffic waste [28, 29] and Zn.201198This is known because of the proximity of point A1 to the highway. Furthermore, the high Mn202199content at point A1 is thought to be the result of post-harvest processing of agricultural land203200[38].

The average Igeo and contamination levels of several metals in soil are shown in Table 2. Igeo is highly variable, implying that the soil surrounding the sampling area was uncontaminated to moderately contaminated in terms of the metals tested. The average concentration of heavy metals was higher in study area A than in site B. Long-term use of machine tools, paints, pigments, and industrial equipment in the study area may have caused the highest Fe content in the soil [10]. The average concentration of Zn, Mn, Cu, and Hg found in study area A was also higher than in study area B. The presence of heavy metals in this area was suspected due to agricultural practices. Pesticides contain the elements Mn, Zn, and Cu (Cu, As, Hg, Pb, Mn, and Zn). Fungicides contain the elements Cu, Zn, and Mn. Compost and manure also contain Zn and Cu. Seed dressings contain Hg [30-32]. 

Zn is present in all sampling points at study area A, but not all sampling points at location B. Zn concentrations were approximately three times higher in sampling points at site A than in sampling points at site B. The average Zn concentration at sites A and B exceeded the 0.06 mg/kg threshold set by the Indonesian National Standardization Agency. However, the Zn concentration at these two sites was still low when compared to agricultural soils in Shenzhen, China (concentration average of 194 mg/kg in the dry season and 209 mg/kg in the rainy season) [33], soil in an unpolluted area of Gebze, China (concentration average 632 mg/kg) [34], and agricultural soil from Huanghuai Plain, China (74 mg/kg) [35]. In contrast to Zn, Cu was distributed over all sampling points in both study locations, and the concentration in site A was ten times higher than in site B. 

The average Cu concentration in both locations also exceeded the 0.04 mg/kg threshold set by the Indonesian National Standardization Agency. However, the concentration of Cu at these two locations was still low when compared to agricultural soils in Shenzhen, China (with an average of 60 mg/kg in the rainy season and 90 mg/kg in the dry season) [33], as well as soils in unpolluted areas in Gebze, China (concentration average 95.88 mg/kg) [34], palm farms' soil in Morocco (concentration average 138 mg/kg) [36], and agricultural soil from Patuakhali District, Bangladesh (4.1–181 mg/kg) [37]. However, the Cu content at Site A was higher than the Cu content in agricultural soils in the Dumuria Upazila, Bangladesh [38] and Marrakech, Morocco [39] areas, whereas the Cu content at Site B was lower than the Cu content in agricultural soils in the Dumuria Upazila, Bangladesh (concentration average 17.70 mg/kg) and Marrakech, Morocco. Cu concentrations are higher in these two locations than in agricultural soils from Jeddah, Arab Saudi Arabia (concentration average 0.4 mg/kg) [40].



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237 233 Hg concentrations were four times higher in site A than in site B. The presence of Hg was 234 suspected to be the result of fungicide use. Hg in soil can be produced by a number of activities, 238 235 including basic metal processing, some chemical sector activities, mining, and industrial waste. 239 Hg concentrations in Gebze soil ranged from 9 to 2.721 g/kg, with an average of 102 g/kg [34], 240 236 241 237 which is significantly higher than the concentrations found in this study. The Hg content of 238 agricultural soils in China's Gorges Dam area is similar to that of this study area (0.08 mg/kg) 242 239 [41]. Hg levels in sites A and B did not exceed the 0.5 mg/kg threshold for its presence in soil. 243 According to this research, the concentration of heavy metals in site A is higher than in site B. 240 244 245 241 According to observations and interviews with local farmers, site A was used for plantation activities much earlier than site B. Heavy metals accumulate in the soil over time due to a 242 246 243 variety of factors, including the use of fertilizers, pesticides, and agricultural equipment [42, 247 244 43]. 248

249 245  $C_f$  was used to determine the overall contamination of the analyzed agricultural soil. The soil 250 246 was classified as having a low contamination factor in both test regions, indicating low 251 247 contamination with Fe, Zn, Mn, Cu, and Hg. The maximum contamination degree ( $C_d$ ) values 252 248 indicated a low level of contamination. As proposed in this work, the m $C_d$  is calculated by 253 249 combining and averaging all available analytical data for a collection of soil samples.

254 250 As a result, this improved method may provide a thorough assessment of the overall 255 251 enrichment and contamination impact of various pollutant groups in the soil. In both sampling 256 252 areas, the mC<sub>d</sub> ranged from 0.48 to 0.10, indicating nil to a very low level of contamination. 257 253 The PLI values indicated that drastic rectification measures are not needed in both areas. Table 258 254 3 shows the soil's average  $C_f^i$ ,  $C_d$ , mC<sub>d</sub> and PLI.

255 Pearson correlation analysis [44] was used to compare all of the variables. Table 4 displays 259 256 the correlation coefficients between metal pairs. High correlation values (R>0.50) between 260 257 different metal pairs, indicating soil accumulation. In soil samples from sampling area A, Mn-261 Zn (R=0.770), Cu-Mn (R=0.656), Hg-Zn (R=0.600), and Hg-Mn (R=0.600) had high 258 262 259 correlation values (R > 0.5). The correlation trends in sampling area B were: Fe-Mn (R=0.965), 263 260 Fe-Cu (R=0.977), and Cu-Mn (R=0.964). 264

Significant correlations indicate that they are thought to be anthropogenic, originating in 261 265 agricultural activities such as the use of fertilizers and pesticides. Both of these areas are about 266 262 263 2 kilometers from Syamsuddin Noer airport, which is thought to contribute to heavy metal 267 268 264 accumulation in the soil in this area [45]. Table 4 also shows the correlation coefficient between each heavy metal content and magnetic susceptibility measured in the same soil plane. 265 269 270 266 According to the correlation analysis of each plot of land, several heavy metals show a positive 267 correlation with magnetic susceptibility values, namely Zn (R=0.555), Mn (R=0.392), and Hg 271 272 268 (R=0.490) in area A, and Zn (R=0.595) and Hg (R=0.367) in area B. When compared to other heavy metals, the content of the heavy metal Zn in both soil planes showed a stronger positive 273 269 274 270 correlation coefficient with magnetic susceptibility. In both sampling areas, heavy metals such as Fe and Cu have negative correlation coefficient values with magnetic susceptibility. 275 271

276 272 Conclusions



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In the biosphere, the soil is an essential component, every harmful change of it can seriously 278 273 274 affect the quality of human life. It is very possible to have heavy metals content in the soil. 279 275 Heavy metals that enter the food chain are the most detrimental because they can threaten 280 276 human health. Some of the agricultural lands in Landasan Ulin, Banjarbaru, South Kalimantan 281 277 are observed in this study. The lands were evaluated for the impact of anthropogenic heavy 282 278 metals by using several indices that showed that study area A was not contaminated until 283 284 279 moderately contaminated by different metals. Meanwhile, study area B did not show any 280 contamination based on all indices. However, the presence of Cu and Zn in this region has 285 exceeded the threshold set by the Indonesian National Standardization Agency, and this must 286 281 282 be watched out for. For this reason, regular monitoring of heavy metals in agricultural land is 287 283 necessary to ensure environmental quality. In addition, remediation measures need to be carried 288 284 out on agricultural land indicated to be contaminated by Cu and Zn. This study also shows that 289 290 285 magnetic susceptibility can be used as a proxy for monitoring the concentration of heavy metal 286 especially Zn in agricultural soil in the Landasan Ulin area. 291

292 287 Acknowledgements

- <sup>293</sup> 288 This study was funded by DIPA Lambung Mangkurat University 2021.
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426	418	Environmental Science and Pollution Research. 25(1), 658, 201	8.
427	419	List of Tables	
428	420	Table 1. Different heavy metal concentrations and magnetic suscer	otibility in the study area's
429	421	agricultural soil Add a descriptive label of the table here.	,
430	422	Table 2. Average $I_{geo}$ and contamination levels of the soil in two sa	mpling areas.
431	423	Table 3. Average $C_{f}^{i}$ , $C_{d}$ , mCd, and PLI of soil over two sampling a	ireas.



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432	Pol. J. Environ. Stud. Vol. X, No. X (2016),	12

433424Table 4. Pearson correlation (R) between heavy metal contents and magnetic susceptibility. The434425value of R for strong (above 0.5) correlation is in bold.

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436	Sampla	Fe	Zn	Mn	Cu	Hg	χıf (× 10 <sup>-8</sup>
	Sample	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	m <sup>3</sup> kg <sup>-1</sup> )
437	Sampling A	Area A					
438	A0	28,600.00	156.00	112.00	49.00	0.12	136.50
439	A1	28,100.00	124.00	161.00	147.00	0.12	135.60
440	A2	27,300.00	77.00	60.00	70.00	0.08	100.10
441	A3	26,900.00	57.00	52.00	70.00	0.11	135.60
442	A4	31,800.00	65.00	70.00	89.00	0.09	47.30
443	A5	30,400.00	71.00	81.00	91.00	0.11	44.80
444	Min	26,900.00	57.00	52.00	49.00	0.08	44.80
445	Max	31,800.00	156.00	161.00	147.00	0.12	136.50
446	Mean	28,850.00	91.67	89.33	86.00	0.10	100.00
447	SD	1,893.94	39.00	41.00	34.00	0.01	44.03
448	Sampling A	Area B					
449	B0	2,500.00	20.00	38.00	7.00	0.01	23.30
450	B1	1,500.00	21.00	23.00	7.00	0.04	21.00
451	B2	1,000.00	65.00	15.00	5.00	0.01	24.30
452	B3	8,200.00	14.00	68.00	12.00	0.01	1.10
453	B4	4,800.00	14.00	39.00	9.00	0.01	1.90
454	B5	1,000.00	20.00	15.00	5.00	0.01	1.60
455	Min	1,000.00	14.00	15.00	5.00	0.01	1.10
456	Max	8,200.00	65.00	68.00	12.00	0.04	24.30
457	Mean	3,166.67	25.67	33.00	7.50	0.01	12.20
458	SD	2,850.03	19.52	20.17	2.66	0.01	11.74
459	Baseline	4.72	95.00	850.00	45.00	0.40	-

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	Sampl	ling Area A	Sampl	ing Area B
Element	T V-1	Contamination	T V-1	Contamination
	Igeo Value	Level	I <sub>geo</sub> value	Level
Fe	-1.3	Unpolluted	-4.94	Unpolluted
Zn	-0.74	Unpolluted	-2.71	Unpolluted
Mn	-3.95	Unpolluted	-5.49	Unpolluted



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467 468 469	Cu	0.27	Moderately to strongly polluted	-3.24	Unpolluted
470	Hg	-2.53	Unpolluted	-5.57	Unpolluted

471 428

472		Sampling area A	Sampling area B
473	C <sub>f</sub> Fe	0.61	0.07
474	C <sub>f</sub> Zn	0.96	0.27
475	C <sub>f</sub> Mn	0.11	0.04
476	C <sub>f</sub> Cu	0.95	0.17
477	$C_{f}Hg$	0.26	0.04
478	Cd	2.89	0.58
479	mCd	0.48	0.1
480	PLI	0.42	0.07

481 429

	Fe	Zn	Mn	Cu	Hg	χlf
Sampling area A						
Fe	1					
Zn	-0.163	1				
Mn	-0.029	0.77	1			
Cu	0.114	0.03	0.656	1		
Hg	-0.145	0.6	0.658	0.239	1	
$\chi_{ m lf}$	-0.831	0.555	0.392	-0.025	0.49	1
		Sampli	ng area B			
Fe	1					
Zn	-0.5	1				
Mn	0.965	-0.541	1			
Cu	0.977	-0.573	0.964	1		
Hg	-0.286	-0.117	-0.243	-0.092	1	
χlf	-0.586	0.595	-0.431	-0.506	0.367	1

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498 431 List of Figures

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499 432 Fig. 1. The sampling site of agriculture soil from vegetable production center in Banjarbaru
500 433 Region



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# SECOND REVISION

Author's Respond Form

Manuscript ID	PJOES-00324-2022-01
Title	Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia
Authors	Sudarningsih Sudarningsih *, Fahruddin Fahruddin, Muhammad Lailiyanto, Alif Antasari Noer, Sadang Husain, Simon Sadok Siregar, Sri Cahyo
	Wahyono, Ichsan Ridwan
Submission date	05 March 2022
Revision date	26 May 2022
Reviewer	2

Editor's Evaluation	Details of Author's Respond	Modification
Editor's Comments	Author's Respond	
R e f e r e n c e s should be indicated in the text by consecutive numbers and the full references should be listed in the same order at the end of the article according to Journal way	This has been revised accordingly	
In references all authors name must be included	This has been revised accordingly	
E-mail address of Corresponding Author must be provided	This has been revised accordingly	
Manuscript should be divided into the sections: Abstract, Keywords, Introduction, Material and Methods (could be omitted in Reviews), Results and Discussion, Conclusions, Acknowledgements, References	This has been revised accordingly	
Answers to all the Reviewer comments	This has been revised accordingly	

Reviewers' Evaluation	Details of Author's Respond	Modification		
<b>Reviewer-1 Comments</b>	Author's Respond			
Authors used only 12 samples which clearly is	This has been revised	See lines 105-108:		
not statically significant. Some justification	accordingly	Twelve agriculture soil samples were taken from two different area (Site A and		
should be given on this.		site B) (Fig.1). Site A in Dahor Formation and site B in alluvial soil [20]. In		
		general, agricultural soils in these two areas tend to be homogeneous with the		
		chemical composition of the soil having low variability [19].		

Reviewers' Evaluation	Details of Author's Respond	Modification				
Reviewer-2 Comments	Author's Respond					
The manuscript should be corrected by removing unnecessary repetitions of data (the same data in Tables and in Figures) and detailed description of sites and sampling points should be added.	This has been revised accordingly					
Summary, line 26 - why Zn is two times	This has been revised accordingly	See line 26: The average concentration of heavy metals in the sampling area A is Fe>Zn>Mn>Cu>Hg, and the area B is Fe>Mn>Zn>Cu>Hg.				
Map with locations of sampling points needed	We have added map with locations of sampling points.	See line 482: Figure 1:				
		Figure 1. The sampling site of agriculture soil from vegetable production center in Banjarbaru Region.				

In how many repetitions analyses were conducted?	This has been revised accordingly	We have r	emoved the	e figures.					
Line 107- Why division into site A and B was performed – what was the difference between thes two sites? Again map with marked Site A and B needed. Pleaese explain shortly this Rahman's method	This has been revised accordingly	See line 482:         Figure 1. The sampling site of agriculture soil from vegetable production center in Banjarbaru Region.         See line 108-113:         These samples were collected using the sampling procedure based on Rahman's methods. Approximately 250–300 g of agricultural soil were collected from the soil surface layer (15–20 cm) using a stainless steel grab sampler. The difference in distance from one sampling point to another in one location is about 100 m. The sample taken is in the center to avoid contact with the inside of the grab sampler material. Samples are checked for possible contamination. Then the sample was transferred to a previously cleaned plastic container [21].							
Table 1. – the same number of decimals should be maintained.	This has been revised accordingly	See line 418: Table 1:							
			Fe	Zn	Mn	Cu	Hg	ν (x 10∗	]
		Sample (mg/	(mg/kg)	(mg/k g)	(mg/kg)	(mg/kg)	(mg/kg)	m <sup>3</sup> kg <sup>4</sup> )	
		Sampling Area A							]
		A0	28,600.0 0	156.00	112.00	49.00	0.12	136.50	
		A1	28,100.0 0	124.00	161.00	147.00	0.12	135.60	
		A2	27,300.0 0	77.00	60.00	70.00	0.08	100.10	
		A3	26,900.0 0	57.00	52.00	70.00	0.11	135.60	
		A4	31,800.0 0	65.00	70.00	89.00	0.09	47.30	
		A5	30,400.0 0	71.00	81.00	91.00	0.11	44.80	
		Min	26,900.0 0	57.00	52.00	49.00	0.08	44.80	
		Max	31,800.0 0	156.00	161.00	147.00	0.12	136.50	
		Mean	28,850.0 0	91.67	89.33	86.00	0.10	100.00	
		SD	1,893.94	39.00	41.00	34.00	0.01	44.03	ļ
		Sampling Area B							

		B0	2,500.00	20.00	38.00	7.00	0.01	23.30	
		B1	1,500.00	21.00	23.00	7.00	0.04	21.00	
		B2	1,000.00	65.00	15.00	5.00	0.01	24.30	
		B3	8,200.00	14.00	68.00	12.00	0.01	1.10	
		B4	4,800.00	14.00	39.00	9.00	0.01	1.90	1
		B5	1,000.00	20.00	15.00	5.00	0.01	1.60	
		Min	1,000.00	14.00	15.00	5.00	0.01	1.10	1
		Max	8,200.00	65.00	68.00	12.00	0.04	24.30	
		Mean	3,166.67	25.67	33.00	7.50	0.01	12.20	-
		SD	2,850.03	19.52	20.17	2.66	0.01	11.74	
		Baselin e	4.72	95.00	850.00	45.00	0.40	-	
Figures 1 – 3 – These are the same data as in Table 1, remove these Figures – they are incorrect, as far as I understand there isn't any connection between f.ex. point "0" in Site A and B, so it is inappropriate to show them as one bar.	We have removed the figures. We have removed Figure 4.								
Figure 4? They both show Igeo but the results are different. And again this is unnecessary repetitions.									
I suggest to expand description of both sites and sampling points and try to explain where such big differences in specific locations come from (f.ex. in site A1).	This has been revised accordingly	See line 18 At site A, which are waste [28, which is c is thought land [38].	31-185: the content suspected of 29], as well losest to the t to also orig	of Mn and come from l as Zn. Th highway ginate fror	d Cu at poin 1 fertilizers 1 fertilizers 1 is knowr 2 in additio 1 n the post-h	nt A1 is hig and pestici n based on t n, the high narvest proo	her than at des [36], als he location content of N cessing of a	other point o from traf of point A vin at point gricultural	ts fic 1 t A1
Description of the way of taking samples is needed.	This has been revised accordingly	See line 108-113: These samples were collected using the sampling procedure based on Rahman methods. Approximately 250–300 g of agricultural soil were collected from th soil surface layer (15–20 cm) using a stainless steel grab sampler. The difference in distance from one sampling point to another in one location is about 100 n The sample taken is in the center to avoid contact with the inside of the gra sampler material. Samples are checked for possible contamination. Then th sample was transferred to a previously cleaned plastic container [21].			an's the ence ) m. grab the				

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Manuscript ID	PJOES-00324-2022-01
Title	Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia
Authors	Sudarningsih Sudarningsih *, Fahruddin Fahruddin, Muhammad Lailiyanto, Alif Antasari Noer, Sadang Husain, Simon Sadok Siregar, Sri Cahyo
	Wahyono, Ichsan Ridwan
Submission date	05 March 2022
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Reviewer	

Editor's Evaluation	Details of Author's Respond	Modification
Editor's Comments	Author's Respond	
R e f e r e n c e s should be indicated in the text by consecutive numbers and the full references should be listed in the same order at the end of the article according to Journal way	This has been revised accordingly	
In references all authors name must be included	This has been revised accordingly	
E-mail address of Corresponding Author must be provided	This has been revised accordingly	
Manuscript should be divided into the sections: Abstract, Keywords, Introduction, Material and Methods (could be omitted in Reviews), Results and Discussion, Conclusions, Acknowledgements, References	This has been revised accordingly	
Answers to all the Reviewer comments	This has been revised accordingly	

Reviewers' Evaluation	Details of Author's Respond		spond	Modification	
Reviewer Comments	Author's	Respo	nd		
In how many repetitions analyses were	This h	as	been	revised	See lines 132-133
conducted?	according	ly			For susceptibility magnetic analyses, each sample was measured with three
	0	5			repetitions. The magnetic susceptibility value used is the average value of the
					results of this measurement [13].
					See lines 134 139
					To analyze the level of heavy metal pollution in an area, more than one pollution
					index analysis is needed $(3, 21, 36, 37)$ , so in this study 5 pollution indices were
					used, namely the geoaccumulation index (Igeo), contamination factor (Cfi), the

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				degree of contamination (Cd), the degree of modified contamination (mCd), and the Pollution Load Index (PLI). The five pollution indices are expected to provide more accurate information on the level of pollution in this research area.
Why division into site A and B was performed	This has accordingly	been	revised	See lines 110-113 In general, agricultural soils in these two areas tend to be homogeneous, with the chemical composition of the soil having low variability [19]. But geologically, these two areas are in two different formations. Site A is in the Dahor Formation and Site B is in alluvial soil [20]. That is why this research is divided into two different research areas.
Also the manuscript would be more valuable if the analyses comprised more samples - in this form it has only local meaning	This has accordingly	been	revised	This research is a local research, because the samples used in this study were collected before the flood in the research area, so it is no longer possible to increase the number of samples with the same conditions as before the flood.
English language needs revision	This has accordingly	been	revised	
Figures : Not acceptable	This has accordingly	been	revised	

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Type of the Paper (Article, Review, Short Communication.)

# **Assessment of Soil Contamination by Heavy Metals: A Case of Vegetable Production Center in Banjarbaru Region, Indonesia**

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### Abstract:

Landasan Ulin is a center for vegetable production, and it has an important role in producing vegetables for the city of Banjarbaru. Agricultural soil in this study was assessed for heavy metal contamination using the geoaccumulation index (Igeo), contamination factor ( $C_f^i$ ), the degree of contamination (Cd), the degree of modified contamination (mCd), and the Pollution Load Index (PLI) as well as magnetic susceptibility. Samples were collected from topsoil and analyzed using magnetic susceptibility and Atomic Absorption Spectrophotometer (AAS). The average concentration of heavy metals in the sampling area A is Fe>Zn>Mn>Cu>Hg, and the area B is Fe>Mn>Zn>Cu>Hg. Magnetic susceptibility values in area A is higher than in area B and the value of magnetic susceptibility can be used as a proxy for monitoring heavy metal concentrations, especially Zn in this area. Zn and Cu exceeded the threshold set by the Indonesian Standards Institute. Igeo results show that the research area is moderately contaminated with Cu, Zn, and Hg. According to  $C_f^i$ , the soil was classified as low contaminated with Fe, Zn, Cu, Mn, and Hg, as well as Cd and mCd. The PLI results show that in both area, drastic corrective action is not required.

**Keywords:** geoaccumulation index; contamination factor; contamination degree; pollution load index

#### Introduction

Heavy metal contamination of agricultural soil due to chemical fertilizers and pesticides is a serious ecological problem today [1, 2]. In agricultural soil, the continuous use of manure and chemical fertilizers for a long time will result in higher heavy metal content [3, 4]. Some heavy metals are needed for the growth of certain plants [5], but some of them for humans can be toxic. When these heavy metals are absorbed and accumulated by plants and then consumed by humans, this will pose a risk to the human body [6].

Some heavy metals have been found in agricultural land in several areas in Indonesia, such as Pb found in soil from 168 locations with different land use and traffic conditions in Yogyakarta, Indonesia [7]. In Semarang, Indonesia, the paddy field contains heavy metals Pb, Cd, and Cu [8]. In agricultural land in Karawang, Pb and Cd were found with concentrations exceeding 1.0 ppm [9]. Meanwhile, in agricultural soils in Bangladesh for the dry season, heavy metals were found with concentrations of As>Fe>Hg>Mn>Zn>Cu>Cr>Ni>Pb>Cd and in the rainy season As>Fe>Mn>Zn>Hg>Cu>Ni>Cr>Pb>Cd [10]. In paddy soils at Hunan Province, China, there was founded heavy metals (Cd, Cr, As, Ni, Mn, Pb, and Hg) in three different locations [11].

The presence of magnetic minerals in the soil can come from weathering of the parent rock (lithogenic origin) and can also come from human activities (anthropogenic). Magnetic minerals that are commonly found in soil are hematite and magnetite. Their presence is in the form of solid waste which can act as the main absorber of pollutants such as heavy metals in the soil. Their presence in the soil will affect the value of the magnetic susceptibility of the soil. The use of magnetic susceptibility has been widely used in various soil science studies, such as soil morphology and genesis as well as tools for mapping the distribution of environmental pollutants [12]. Magnetic susceptibility measurement has been considered as a fast and cheapest monitoring tool for determining the spatial distribution of heavy metal presence in soil and can be used as a proxy for chemical methods [13]. Research using the method of environmental magnetism in Indonesia is still few in number. Several studies were conducted to examine the river and lake environment [14–17] Therefore, this study is very important.

Landasan Ulin is a vegetable center production in Banjarbaru City, South Kalimantan, Indonesia. Agricultural activities in this area are carried out by farmers traditionally [18]. Meanwhile, agricultural land has the potential to experience heavy metal pollution, and studies on heavy metal pollution in agriculture in this area are still rarely carried out. Therefore, it is very important to conduct this research to determine the current status of the presence of these heavy metals on the surface of agricultural soil. This will be of benefit to ameliorate the impacted environmental problems further, and to adopt mitigation strategies in the future. This study aims to investigate the level of contamination of various heavy metals (Fe, Mn, Cu, Zn, Hg) in agricultural land located in Landasan Ulin, South Kalimantan, Indonesia, using different indices such as geoaccumulation index, pollution factor, degree of pollution, and the pollution load index. The correlation between heavy metal contamination and magnetic susceptibility is also investigated in this study. These results can be used as an alternative method in determining heavy metal contamination in agricultural areas. This approach will help monitor the presence of heavy metals in agricultural soils and soil remediation. Monitoring for polluted areas is crucial, and it is beneficial for the sustainability of pollution management and control in the future.

#### **Materials and Methods**

Study Area

#### Sampling and Measurements

# Index of Geoaccumulation, Contamination Factor ( $C_{f}^{i}$ ), Degree of Contamination (Cd) and Pollution Load Index (PLI)

Landasan Ulin, South Kalimantan Province, Indonesia, has a 92.42 km2 area, consisting of mountains and hills in the north and east, and lowlands to the west, while the south has alluvium and swamp areas. Landasan Ulin is about 40 km from the provincial capital, Banjarmasin. Landasan Ulin is a vegetable production area in South Kalimantan. The cultivated vegetables from the area include mustard greens, kale, spinach, eggplant, lettuce, long beans, peanuts, and scallions. One of the efforts to increase the yield and quality of vegetables is through fertilization. Both organic and inorganic fertilizers are applied. The used dose of organic fertilizer was 485 kg, or an average of 16.17 kg/farmer, while the inorganic fertilizer was 556 kg, or an average of 18.53 kg/farmer. Nitrogen (N) fertilizer is critical for the growth of vegetables. The crops are never separated from the disturbance of weeds and pests. Theoretically, weeds are bothering vegetable growth because they are competitive in many ways, especially in getting water, sunlight, and nutrients. Weeds also, in some cases, become the source of the disease that often becomes a significant threat to the corps. To manage the growth of weeds, farmers do the chemical control of weeds regularly by using Gramoxon. About 400 liters is enough to kill weeds on an average of 13.33 liters/respondent. Removing the weeds can also be done manually by using physical measures or machinery. Meanwhile, in overcoming pests and diseases in North Landasan Ulin Village, the farmers used Ampligo, one of the pesticide brands. It is sprayed regularly with a dose that ranges from 20 liters or an average of 0.67 liters/farmer to kill/destroy pests that stick around the leaves and stems of mustard greens [19].

Twelve agriculture soil samples were taken from two different area (Site A and site B) (Fig.1). In general, agricultural soils in these two areas tend to be homogeneous, with the chemical composition of the soil having low variability [19]. But geologically, these two areas are in two different formations. Site A is in the Dahor Formation and Site B is in alluvial soil [20]. That is why this research is divided into two different research areas. These samples were collected using the sampling procedure based on Rahman's methods. Approximately 250–300 g of agricultural soil were collected from the soil surface layer (15–20 cm) using a stainless steel grab sampler. The difference in distance from one sampling point to another in one

location is about 100 m. The sample taken is in the center to avoid contact with the inside of the grab sampler material. Samples are checked for possible contamination. Then the sample was transferred to a previously cleaned plastic container [21]. In the laboratory, the soil sample was dried by aerating at room temperature. The dry soil samples were sieved using a 325 meshsize sieve (44  $\mu$ m in diameter) to obtain homogeneous soil particles. 2–3 g dry soil samples were digested in about 15 mL of aqua-regia (HCL: HNO3 = 3:1) for about 4–5 hours on a hotplate set to 110 °C. The materials were then diluted to 50 mL in a 100 mL Pyrex glass beaker with distilled water. In the laboratory of the Indonesian Geological Survey in Bandung, Indonesia, by AA280FS Atomic Absorption Spectrometer (AAS) (Variant Inc. Palo Alto, USA), the solution was filtered, and the filtrates were examined. The working standard solutions for each metal were prepared before every analysis. An air acetylene flame AAS was used to measure Fe, Zn, Cu, Pb, and Mn concentrations, with As determined by hydride vapor generation AAS. Magnetic susceptibility measurement was carried out in the following way, the dried soil sample was put into a cylindrical plastic holder with a diameter of 25.4 mm and a height of 22 then measured using a Susceptibilitymeter (Bartington Instrument Ltd., Oxford, UK). Each sample was measured with three repetitions. The magnetic susceptibility value used is the average value of the results of this measurement [13].

To analyze the level of heavy metal pollution in an area, more than one pollution index analysis is needed (3, 21, 36, 37), so in this study 5 pollution indices were used, namely the geoaccumulation index ( $I_{geo}$ ), contamination factor ( $_{Cfi}$ ), the degree of contamination (Cd), the degree of modified contamination (mCd), and the Pollution Load Index (PLI). The five pollution indices are expected to provide more accurate information on the level of pollution in this research area.

Müller's geoaccumulation index (Igeo) [22], which was originally established to measure contamination of sedimentary bottoms, may now be used to assess soil contamination. It's calculated using equation (1) as follows:

$$I_{geo} = \log_2 \frac{C_n}{1.5B_n} (1)$$

Cn is the element's observed concentration in the pelitic sedimentary fraction (<2 m), and Bn is the geochemical background value based on argillaceous sedimentary fossils (shale mean).  $C_f^i$ and  $C_d$  are indices that can be used to assess soil contamination which consists of four classes [23]. Equation (2) was utilized in the following way:

$$C_{f}^{i} = \frac{C_{0}^{i}}{C_{n}^{i}}(2)$$

 $C_0^{i}$  is the pre-industrial concentration of the specific metal, and  $C_n^{i}$  is the mean content of metals from at least five sampling sites. As a result, the computed  $C_d$  is defined as the amount of  $C_f^{i}$  determined by Hakanson for the polluting species [23]. The following is the equation used to calculate  $C_d$ 

$$C_d = \sum_{i=1}^n C_f^i (3)$$

 $C_d$  is intended to measure the overall level of contamination in the surface layer at a particular sampling site. In this study, we applied a factor modification as applied by Krzysztof [24]. Abrahim [25] proposes the following modified and generalized version of the Hakanson equation [23] for estimating the total degree of contamination at a sample or coring location. Equation 4 is a modified equation for the general approach to calculating contamination levels.  $\boxed{mC_d = \frac{\sum_{i=1}^{i=n} C_f^i}{n}}_{(4)}$ 

Where n denotes the number of elements to be examined and the contamination factor is abbreviated as  $C_f^{i}$ . Using this formula to compute mC<sub>d</sub> allows metals to be incorporated into studies with no upper limit. To identify pollution, Tomlinson created the pollutant load index (PLI) [26]. This index allows for comparisons of pollution levels between sites and across time. The PLI was calculated as a concentration factor for each heavy metal in relation to the soil background value. The background for the heavy metal in this investigation was the average world concentration of the examined metal reported for shale [27]. PLI can assess the level of metal contamination and the actions that must be taken. The formulas used are in the form of equations (5).

 $\overline{\text{PLI} = n\sqrt{\text{C}_{f1} \times \text{C}_{f2} \times ... \times \text{C}_{fn}}}(5)$ 

## **Results and Discussion**

Heavy metal Content and Magnetic susceptibility Soil Pollution Degree Correlation Between Heavy Metal Content and Magnetic Susceptibility

Table 1 shows the average concentrations of a number of metals in the agricultural soils of the study area. The average Fe, Zn, Mn, Cu, and Hg concentrations in study area A were 28,850.00, 91.67, 89.33, 86.00, and 0.10 mg/kg. The average amounts of Fe, Zn, Mn, Cu, and Hg in B were 3,166.00, 25.67, 33.00, 7.50, and 0.01 mg/kg, respectively. Metal trends in research area A are Fe>Zn>Mn>Cu>Hg. Meanwhile, the trends of metals according to the average concentration in study area B is: Fe>Mn>Zn>Cu>Hg. Due to the agronomic practice, the concentration of heavy metals in study area B was various. Meanwhile, metal concentration trends in study area B are as follows: Fe>Mn>Zn>Cu>Hg. The concentration of heavy metals in study area B varied due to agronomic practices. The low heavy metal concentration in the soil can be attributed to the constant elimination of heavy metals by vegetables grown in the designated regions [21]. Table 1 also includes the magnetic susceptibility values of the samples from areas A and B. In general, the magnetic susceptibility values of area A  $(100.0 \times 10^{-8} \text{ m}^3\text{kg}^-)$ <sup>1</sup>) were 9 times greater than those of area B ( $12.2 \times 10^{-8} \text{ m}^3\text{kg}^{-1}$ ). Magnetic susceptibility of sampling area A ranges from 44.8 to  $136.5 \times 10^{-8} \text{ m}^3\text{kg}^{-1}$ , while magnetic susceptibility of sampling area B ranges from 1.1 to  $24.3 \times 10^{-8} \text{ m}^3\text{kg}^{-1}$ . Agricultural practices, such as the use of magnetic minerals such as Fe in fertilizers and pesticides, can increase the magnetic mineral content of agricultural soil. Magnetic minerals in agricultural soil can also be found in

household waste. As is well known, the research site, area A, is located very close to settlements, whereas area B is located far from settlements. Household waste contains anthropogenic magnetic minerals, which can raise the magnetic susceptibility value [28].

The content of Mn and Cu at point A1 in area A is higher than at other points, which are suspected to be from fertilizers and pesticides [36], as well as traffic waste [28, 29] and Zn. This is known because of the proximity of point A1 to the highway. Furthermore, the high Mn content at point A1 is thought to be the result of post-harvest processing of agricultural land [38].

The average Igeo and contamination levels of several metals in soil are shown in Table 2. Igeo is highly variable, implying that the soil surrounding the sampling area was uncontaminated to moderately contaminated in terms of the metals tested. The average concentration of heavy metals was higher in study area A than in site B. Long-term use of machine tools, paints, pigments, and industrial equipment in the study area may have caused the highest Fe content in the soil [10]. The average concentration of Zn, Mn, Cu, and Hg found in study area A was also higher than in study area B. The presence of heavy metals in this area was suspected due to agricultural practices. Pesticides contain the elements Mn, Zn, and Cu (Cu, As, Hg, Pb, Mn, and Zn). Fungicides contain the elements Cu, Zn, and Mn. Compost and manure also contain Zn and Cu. Seed dressings contain Hg [30-32].

Zn is present in all sampling points at study area A, but not all sampling points at location B. Zn concentrations were approximately three times higher in sampling points at site A than in sampling points at site B. The average Zn concentration at sites A and B exceeded the 0.06 mg/kg threshold set by the Indonesian National Standardization Agency. However, the Zn concentration at these two sites was still low when compared to agricultural soils in Shenzhen, China (concentration average of 194 mg/kg in the dry season and 209 mg/kg in the rainy season) [33], soil in an unpolluted area of Gebze, China (concentration average 632 mg/kg) [34], and agricultural soil from Huanghuai Plain, China (74 mg/kg) [35]. In contrast to Zn, Cu was distributed over all sampling points in both study locations, and the concentration in site A was ten times higher than in site B.

The average Cu concentration in both locations also exceeded the 0.04 mg/kg threshold set by the Indonesian National Standardization Agency. However, the concentration of Cu at these two locations was still low when compared to agricultural soils in Shenzhen, China (with an average of 60 mg/kg in the rainy season and 90 mg/kg in the dry season) [33], as well as soils in unpolluted areas in Gebze, China (concentration average 95.88 mg/kg) [34], palm farms' soil in Morocco (concentration average 138 mg/kg) [36], and agricultural soil from Patuakhali District, Bangladesh (4.1–181 mg/kg) [37]. However, the Cu content at Site A was higher than the Cu content in agricultural soils in the Dumuria Upazila, Bangladesh [38] and Marrakech, Morocco [39] areas, whereas the Cu content at Site B was lower than the Cu content in agricultural soils in the Dumuria Upazila, Bangladesh (concentration average 17.70 mg/kg) and Marrakech, Morocco. Cu concentrations are higher in these two locations than in agricultural soils from Jeddah, Arab Saudi Arabia (concentration average 0.4 mg/kg) [40]. Hg concentrations were four times higher in site A than in site B. The presence of Hg was suspected to be the result of fungicide use. Hg in soil can be produced by a number of activities, including basic metal processing, some chemical sector activities, mining, and industrial waste. Hg concentrations in Gebze soil ranged from 9 to 2.721 g/kg, with an average of 102 g/kg [34], which is significantly higher than the concentrations found in this study. The Hg content of agricultural soils in China's Gorges Dam area is similar to that of this study area (0.08 mg/kg) [41]. Hg levels in sites A and B did not exceed the 0.5 mg/kg threshold for its presence in soil. According to this research, the concentration of heavy metals in site A is higher than in site B. According to observations and interviews with local farmers, site A was used for plantation activities much earlier than site B. Heavy metals accumulate in the soil over time due to a variety of factors, including the use of fertilizers, pesticides, and agricultural equipment [42, 43].

 $C_f$  was used to determine the overall contamination of the analyzed agricultural soil. The soil was classified as having a low contamination factor in both test regions, indicating low contamination with Fe, Zn, Mn, Cu, and Hg. The maximum contamination degree ( $C_d$ ) values indicated a low level of contamination. As proposed in this work, the m $C_d$  is calculated by combining and averaging all available analytical data for a collection of soil samples.

As a result, this improved method may provide a thorough assessment of the overall enrichment and contamination impact of various pollutant groups in the soil. In both sampling areas, the mC<sub>d</sub> ranged from 0.48 to 0.10, indicating nil to a very low level of contamination. The PLI values indicated that drastic rectification measures are not needed in both areas. Table 3 shows the soil's average  $C_f^i$ ,  $C_d$ , mC<sub>d</sub> and PLI.

Pearson correlation analysis [44] was used to compare all of the variables. Table 4 displays the correlation coefficients between metal pairs. High correlation values (R>0.50) between different metal pairs, indicating soil accumulation. In soil samples from sampling area A, Mn-Zn (R=0.770), Cu-Mn (R=0.656), Hg-Zn (R=0.600), and Hg-Mn (R=0.600) had high correlation values (R> 0.5). The correlation trends in sampling area B were: Fe-Mn (R=0.965), Fe-Cu (R=0.977), and Cu-Mn (R=0.964).

Significant correlations indicate that they are thought to be anthropogenic, originating in agricultural activities such as the use of fertilizers and pesticides. Both of these areas are about 2 kilometers from Syamsuddin Noer airport, which is thought to contribute to heavy metal accumulation in the soil in this area [45]. Table 4 also shows the correlation coefficient between each heavy metal content and magnetic susceptibility measured in the same soil plane. According to the correlation analysis of each plot of land, several heavy metals show a positive correlation with magnetic susceptibility values, namely Zn (R=0.555), Mn (R=0.392), and Hg (R=0.490) in area A, and Zn (R=0.595) and Hg (R=0.367) in area B. When compared to other heavy metals, the content of the heavy metal Zn in both soil planes showed a stronger positive correlation coefficient with magnetic susceptibility. In both sampling areas, heavy metals such as Fe and Cu have negative correlation coefficient values with magnetic susceptibility.

#### Conclusions

In the biosphere, the soil is an essential component, every harmful change of it can seriously affect the quality of human life. It is very possible to have heavy metals content in the soil. Heavy metals that enter the food chain are the most detrimental because they can threaten human health. Some of the agricultural lands in Landasan Ulin, Banjarbaru, South Kalimantan are observed in this study. The lands were evaluated for the impact of anthropogenic heavy metals by using several indices that showed that study area A was not contaminated until moderately contaminated by different metals. Meanwhile, study area B did not show any contamination based on all indices. However, the presence of Cu and Zn in this region has exceeded the threshold set by the Indonesian National Standardization Agency, and this must be watched out for. For this reason, regular monitoring of heavy metals in agricultural land is necessary to ensure environmental quality. In addition, remediation measures need to be carried out on agricultural land indicated to be contaminated by Cu and Zn. This study also shows that magnetic susceptibility can be used as a proxy for monitoring the concentration of heavy metal especially Zn in agricultural soil in the Landasan Ulin area.

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List of Tables

Table 1. Different heavy metal concentrations and magnetic susceptibility in the study area's agricultural soil Add a descriptive label of the table here.

Table 2. Average Igeo and contamination levels of the soil in two sampling areas.

Table 3. Average  $C_{f}^{i}$ ,  $C_{d}$ , mCd, and PLI of soil over two sampling areas.

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The Tab .g (a ).3)

Samula	Fe	Zn	Mn	Cu	Hg	χıf (× 10 <sup>-8</sup>
Sample	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	m <sup>3</sup> kg <sup>-1</sup> )
Sampling	Area A					
A0	28,600.00	156.00	112.00	49.00	0.12	136.50
A1	28,100.00	124.00	161.00	147.00	0.12	135.60
A2	27,300.00	77.00	60.00	70.00	0.08	100.10
A3	26,900.00	57.00	52.00	70.00	0.11	135.60
A4	31,800.00	65.00	70.00	89.00	0.09	47.30
A5	30,400.00	71.00	81.00	91.00	0.11	44.80
Min	26,900.00	57.00	52.00	49.00	0.08	44.80
Max	31,800.00	156.00	161.00	147.00	0.12	136.50
Mean	28,850.00	91.67	89.33	86.00	0.10	100.00
SD	1,893.94	39.00	41.00	34.00	0.01	44.03
Sampling	Area B					
B0	2,500.00	20.00	38.00	7.00	0.01	23.30
B1	1,500.00	21.00	23.00	7.00	0.04	21.00
B2	1,000.00	65.00	15.00	5.00	0.01	24.30
B3	8,200.00	14.00	68.00	12.00	0.01	1.10
B4	4,800.00	14.00	39.00	9.00	0.01	1.90
B5	1,000.00	20.00	15.00	5.00	0.01	1.60
Min	1,000.00	14.00	15.00	5.00	0.01	1.10
Max	8,200.00	65.00	68.00	12.00	0.04	24.30
Mean	3,166.67	25.67	33.00	7.50	0.01	12.20
SD	2,850.03	19.52	20.17	2.66	0.01	11.74
Baseline	4.72	95.00	850.00	45.00	0.40	-

ble 4. Pearson correlation (R) between heavy metal contents and magnetic susceptibility.	
value of R for strong (above 0.5) correlation is in bold.	

	Samp	ling Area A	Sampling Area B		
Element	T Valaa	Contamination	I V-1	Contamination	
	I <sub>geo</sub> value	Level	I <sub>geo</sub> value	Level	
Fe	-1.3	Unpolluted	-4.94	Unpolluted	
Zn	-0.74	Unpolluted	-2.71	Unpolluted	
Mn	-3.95	Unpolluted	-5.49	Unpolluted	

Cu	0.27	Moderately to strongly polluted	-3.24	Unpolluted
Hg	-2.53	Unpolluted	-5.57	Unpolluted

	Sampling area A	Sampling area B
C <sub>f</sub> Fe	0.61	0.07
C <sub>f</sub> Zn	0.96	0.27
C <sub>f</sub> Mn	0.11	0.04
C <sub>f</sub> Cu	0.95	0.17
С <sub>f</sub> Нg	0.26	0.04
Cd	2.89	0.58
mCd	0.48	0.1
PLI	0.42	0.07

	Fe	Zn	Mn	Cu	Hg	χlf	
Sampling area A							
Fe	1						
Zn	-0.163	1					
Mn	-0.029	0.77	1				
Cu	0.114	0.03	0.656	1			
Hg	-0.145	0.6	0.658	0.239	1		
$\chi_{ m lf}$	-0.831	0.555	0.392	-0.025	0.49	1	
		Sampli	ng area B	5			
Fe	1						
Zn	-0.5	1					
Mn	0.965	-0.541	1				
Cu	0.977	-0.573	0.964	1			
Hg	-0.286	-0.117	-0.243	-0.092	1		
χlf	-0.586	0.595	-0.431	-0.506	0.367	1	

]

# List of Figures

Fig. 1. The sampling site of agriculture soil from vegetable production center in Banjarbaru Region



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Assessment of Soil Contamination by Heavy

Metals: A Case of Vegetable Production Center

in Banjarbaru Region, Indonesia

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