

## ***Interactive comment on “Multifractal characteristic-based comparison of elements in soils within the Daxing and Yicheng areas of Hefei, Anhui Province, China” by X. Li et al.***

**X. Li et al.**

yf\_hfut@163.com

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Specific comments to the authors:

Please, organize the manuscript in Introduction, Materials and Methods, Results and Discussion, and Conclusions.

Title:

I suggest the authors to slightly modify the title of their manuscript to: “Comparison of the multifractal characteristics of heavy metals in soils within two areas of contrasting economic activities in China”.

C1

We thank the reviewer for their suggestion and have modified the title of our manuscript as follows: “Comparison of the multifractal characteristics of heavy metals in soils within two areas of contrasting economic activities in China”.

Abstract:

The abstract is too long from my point of view.

We have shortened the abstract to highlight the main findings of our research.

Lines 16-17: “causing” instead of “that can have”.

We have used “causing” instead of “that can have”.

Line 23; “allows deeper interrogation”, this expression is not clear. Please, re-phrase it.

We have revised this sentence to "Here, we present the results of a heavy metal (Cu, Pb, Zn, Cd, As and Hg) soil geochemical survey and use these data to evaluate and compare the characteristics of heavy metal pollution in soil in urban or developed areas."

Lines 26-28: “This study focuses. . .”, this sentence can be removed since its information is reported in the next one.

We have removed this sentence.

Line 29: Include “(industrial)” after “Daxing” and “(agricultural)” after “Yicheng”.

We have changed this sentence to "This study uses a multifractal spectral technique to identify the multifractality in the geochemistry of soils within the industrial Daxing and agricultural Yicheng areas of Anhui Province".

Lines 31, 32 and 38: Use  $\alpha$  instead of  $a$  in  $\Delta f(\alpha)$ , please.

We have used  $\alpha$  instead of  $a$  in  $\Delta f(\alpha)$ .

C2

Line 33: There is a mistake here; according to table 2, the  $\Delta f(\alpha)$  in Yicheng decreased as Zn>Hg>As>Cd>Pb>Cu instead of Hg>Zn>As>Cd>Pb>Cu as is reported here.

We thank the reviewer for pointing out this mistake and for providing us with a new idea. Previously we thought that using  $f(\alpha)$  to study contamination was sufficient, but we now realise that this is not sufficient and that  $\Delta\alpha$ ,  $\Delta f(\alpha)$  and  $\tau''(1)$  values also reflect different aspects of multifractality. As such, we have used  $\Delta\alpha$ ,  $\Delta f(\alpha)$  and  $\tau''(1)$  together in the revised manuscript to study and evaluate the multifractality of heavy metal contamination in the study area.

Line 34: I would remove the word "geochemical".

We have removed the word "geochemical".

Line 36: "clearly different" instead of "distinctly different".

We have changed "distinctly different" to "clearly different".

Lines 44-45: I would remove "rather than a single approach to heavy metal pollution" since it is not needed.

We have removed these words.

Introduction:

This section is not clear, the state-of-the-art is not put into context and thus the introduction seems out of focus. Moreover, this section begins with a list of references because in the first 6 lines, authors cited 13 references.

We have reorganized the introduction as recommended by the reviewer.

Line 51: I would remove "recently".

We have removed "recently".

Lines 58-59: "the factors controlling the distribution" instead of "the controls on the distribution".

C3

We have changed "the controls on the distribution" to "the factors controlling the distribution".

Line 62: "in soil properties" instead of "in the characteristics of soils".

We have changed "in the characteristics of soils" to "in soil properties".

Line 63: Remove "and".

We have removed "and".

Lines 63-65: Please, check English, this sentence is unclear.

We have reorganized this sentence.

Lines 67-68: "but also in the analysis of" instead of "but can also be used in the analysis of".

We have changed "but can also be used in the analysis of" to "but also in the analysis of".

Line 70: "and thus" instead of "meaning that".

We have changed "meaning that" to "and thus".

Lines 73-75: Please, re-phrase this sentence. It is not clear what you mean and must be put in context with the former sentence.

We have reorganized this sentence.

Line 77: Please, define "C-A" when first used.

We have used "Concentration-Area" instead of "C-A".

Line 79: Please, define "S-A" when first used.

We have used the "Spectral density-Area" instead of "S-A".

Lines 78-83: This is not clear, please, revise it.

C4

We have reorganized this sentence.

Line 86: Remove "provincial".

We have removed this word.

Line 87: Remove "areas".

We have removed this word.

Line 88: "activities" instead of "activity".

We have changed "activity" to "activities".

Lines 88-96: This portion of the text is repetitive and unclear. Please, revise it and state clearly the aims of your study.

We have reorganized these sentences to make the text more clear and more concise as follows:

"Here, we use multifractal techniques to determine the multifractal characteristics of the distribution of heavy metals in soils in these areas, using three multifractal parameters ( $\Delta\alpha$ ,  $\Delta f(\alpha)$  and  $\tau^{(1)}$ ) to analyse and compare the degree and characteristics of the multifractality of heavy metal contamination in soils associated with the anthropogenic activities in this region. The results will further enable and inform future planning for any necessary remediation of these soils in the Daxing and Yicheng areas."

Study area and geochemical data:

Line 99: Include "it" before "has". Line 102: "industrial areas of Hefei" instead of "industrial bases of the Hefei area".

We have added "it" before "has" and used "industrial areas of Hefei" instead of "industrial bases of the Hefei area".

Line 103: Remove the word "industrial".

C5

We have removed this word.

Line 105-106: "In contrast, the town of Yicheng focuses its economic activities on agricultural production" instead of "In contrast, the town of Yicheng is agricultural, with the economy of the town focused on agricultural production".

We have used "In contrast, the town of Yicheng focuses its economic activities on agricultural production" instead of "In contrast, the town of Yicheng is agricultural, with the economy of the town focused on agricultural production".

Line 107: "ornamentals" instead of "flower planting".

We have used "ornamentals" instead of "flower planting".

Line 110: I do not understand what you mean by "natural mineralization".

Here, we want to show that the soil in these areas are not influenced by mineralization or deposits.

Lines 110-111: "< 20 cm depth)" instead of "<20 cm below surface)".

We have used "<20 cm depth)" instead of "<20 cm below surface)".

Line 114: "was air-dried" instead of "was dried in air".

We have used "was air-dried" instead of "was dried in air".

Line 117: Remove "in the soil samples described above", remove also "during this study".

We have removed these words.

Line 119: "whereas Hg and As concentrations were determined" instead of "with Hg and As concentrations determined".

We have used "whereas Hg and As concentrations were determined" instead of "with Hg and As concentrations determined".

C6

Lines 122-125: You repeat too many times the word “analysis”, sometimes you can use the synonym “determinations”.

We thank the reviewer for this suggestion and have revised this sentence to "The accuracy of these data was monitored by repeat determinations of standards and replicate determinations of sub-sets of samples using instrumental neutron activation analysis (INAA). Analytical precision was monitored using determinations of variance of the results obtained from duplicate analyses."

Lines 116-125: Have you got references for the analytical methods? If so, please, add them to this portion of the text.

We think these analytical methods are well known as they have been used for a significant period of time and we do not want to make the reference list longer; as such, we have not made any specific reference to these techniques in the manuscript.

Line 126: “2.3. Results”, this should be a section after the explanations of the materials and methods used.

We have moved this paragraph to Section 4.

Line 127: “A statistical summary” instead of “The results of a statistical analysis”.

We have used “A statistical summary” instead of “The results of a statistical analysis”.

Line 134: “the natural background”. Maybe you should indicate what was the natural background.

Our original phrasing was not accurate; as such, we have changed this sentence to "This also suggests that samples from the Daxing area containing elevated concentrations of heavy metals were probably contaminated by anthropogenic activity."

Line 136: I would include Pb with Cu for the Yicheng area since the distribution of its concentrations in soils seems to follow a normal distribution as well.

C7

We thank the reviewer for their suggestion and have revised the manuscript appropriately.

Line 137: I would include “(Fig. 2)” after “outliers”.

We have moved “(Fig. 2)” after “outliers”.

Line 138: I am not sure, I agree that they are non-normal but how can you tell from the histograms that they are fractal?

We are only speculating that these data have fractal distributions in this section; as such, we have changed the text to reflect this as follows: "indicating that these data have non-normal and potentially fractal- or multifractal-type distributions."

Line 140: Remove “(Fig. 2)” from here.

We have removed “(Fig. 2)” from here.

Lines 143-146: I would rephrase this figure caption to “Location of Hefei in central-eastern China (a); location of the study areas within Hefei (b); 1 x 1 km grid for soil sampling in the towns of Daxin (c) and Yicheng (d)”.

We have changed this figure caption.

Line 148: Re-phrase the title of this table to “Summary statistics of soil heavy metal concentrations from the Daxing and Yicheng samples”.

We have changed this figure caption.

Table 1: Skewness and kurtosis are not concentrations and they are dimensionless. I would put the units below each column title, I mean below “minimum”, “maximum”, “mean” and “standard deviation”. I would remove “Concentrations” from the table.

We thank the reviewer for this suggestion and have revised this table accordingly.

Multifractal spectrum analysis:

C8

Equations should be numbered.

We have numbered all of the equations in the text.

Line 159: “the factors controlling the distribution” instead of “the controls on the distribution”. What do you mean by “of key elements within data”.

We have changed the “the controls on the distribution” to “the factors controlling the distribution”.

The key elements we want to express are the important study objects within the data, such as the heavy metals, nutrition component, porosity of soil, and so on.

Line 160: Remove the word “multifractal”. “ $f(\alpha)$ ” instead of “ $f(a)$ ”.

We have removed the word “multifractal” and now use “ $f(\alpha)$ ” instead of “ $f(a)$ ”.

Line 163: Remove “of estimating  $f(a)$  values” since it is not needed.

We have removed the words “of estimating  $f(a)$  values”.

Line 170: “different from 0” instead of “that  $\neq 0$ ”.

We have changed this to “different from 0” instead of “that  $\neq 0$ ” as suggested by the reviewer.

Lines 173-174: Move “within a dataset” to after “statistical estimation”.

We have moved “within a dataset” to after “statistical estimation”

Line 183: “different from 0” instead of “that  $\neq 0$ ”.

We have changed this to “different from 0” from “that  $\neq 0$ ”

Lines 184-185: Use alpha ( $\alpha$ ) instead of a when referring to the multifractal spectra.

We have changed this throughout the manuscript.

Line 194: “spectrum is” instead of “spectrum are”.

C9

We have used “spectrum is” instead of “spectrum are”.

Line 197: Use alpha ( $\alpha$ ) instead of a when referring to the multifractal spectra.

We have changed this throughout the manuscript.

Line 201: “by the following” instead of “using the following”.

We have used “by the following” instead of “using the following”.

Calculation processes and discussion:

Lines 205-209: This has already been said in the former section.

We have removed these sentences from this section.

Line 214: Remove “that” and “all of”.

We have removed these words.

Lines 217-223: This description should be greatly improved. Check English, please. Only Cu and Pb for Yicheng area have  $\tau''(1)$  values lower than -0.01.

We have revised this sentence as follows as per the reviewer’s comments:

“The multifractal analytical results shown in Table 2 indicate that all of the elements (barring Cu in the Yicheng area) are characterized by a wide range of  $\alpha$  values (i.e. have high  $\Delta f(\alpha)$  values), have  $\tau''(1)$  values less than -0.01 (barring Cu and Pb in the Yicheng area) and have  $\Delta f(\alpha)$  values larger than 0.5 (barring Cu in the Yicheng area), all of which indicate that these elements have highly multifractality within the soils in these two areas”.

Line 225: Use “indices” instead of “elements”. You are not talking about the elements but the multifractal indices that you obtained.

The revised version of this manuscript uses three multifractal parameters to study the multifractality of the heavy metal distribution in soils in the study area. We have

C10

amended the text to reflect this as follows:

"The overall amount of multifractality within the soil geochemical data for the Daxing area decreases as follows: Pb>Cd>As>Zn>Hg>Cu, whereas the overall amount of multifractality within the soil geochemical data for the Yicheng area decreases as follows: Hg>Zn>As>Cd>Pb>Cu".

Line 226: "decrease" instead of "decreases". There is a mistake here, Zn have a greater  $f(\alpha)$  value than Hg for the Yicheng samples.

We have corrected the text and have discussed all three of the multifractal parameters within the text.

Line 227: This has already been observed in the statistical summary.

We have removed this sentence. However, we have also compared the differences between the statistical summary and the results of our multifractal analysis as follows: "Table 3 indicates that the Zn data has largest standard deviation and a moderate coefficient of variation within the Daxing area, but the  $\Delta\alpha$  and  $\Delta f(\alpha)$  values for these Zn data indicate only weak multifractality compared with other heavy metals. In comparison, the Hg data for soils in the Yicheng area yields the lowest standard deviation but the largest  $\Delta\alpha$  and  $\tau''(1)$  values, indicating these Hg data have strong multifractality. These differences indicate that the multifractal parameters  $\Delta\alpha$ ,  $\Delta f(\alpha)$  and  $\tau''(1)$  reveal new information about the nonlinear variability and the characteristics of these geochemical data compared to the analyses afforded by classic basic statistics".

Line 229-231: In fact, you are plotting these data.

We have deleted this sentence to make the text more logical.

Lines 232-234: This is not clear. Please, re-phrase it.

We have revised this paragraph, as follows:

"Multifractal spectra combine the singularity exponent  $\alpha$  and the corresponding fractal

C11

dimension  $f(\alpha)$  to generate a multifractal spectrum with an inverse bell shape (Fig. 3). All of these multifractal spectra are also asymmetric ( $\Delta\alpha_L$  is significantly different from  $\Delta\alpha_R$ , equations 5-6) (barring the Cu data for soils from the Yicheng area), indicating that the soils containing low and high concentrations of these elements are not evenly distributed within the study area (as is expected for areas containing point source pollutants like factories or animal breeding facilities)."

Line 235: Remove "for all elements".

We have removed "for all elements".

Lines 235-240: I am not sure about understanding this. Please, re-phrase it.

We have revised this sentence as follows:

"All of these multifractal spectra are also asymmetric ( $\Delta\alpha_L$  is significantly different from  $\Delta\alpha_R$ , equations 5-6) (barring the Cu data for soils from the Yicheng area), indicating that the soils containing low and high concentrations of these elements are not evenly distributed within the study area (as is expected for areas containing point source pollutants like factories or animal breeding facilities)."

Line 241: "heavy metal contamination of soil" instead of "heavy metal contamination soil contamination".

We have used "heavy metal contamination of soil" instead of "heavy metal contamination soil contamination".

Line 243: "Yicheng area is caused by Hg" instead of "Yicheng area is Hg contamination".

We have used "would be mainly caused by Hg" instead of "is Hg contamination".

Lines 243-244: This is not true. According to table 2, As has a very similar  $\Delta f(\alpha)$  value than that of Hg and the value for Zn is even greater than that of Hg.

C12

We have updated this and now use three multifractal parameters to discuss the results of our study.

Line 247: “because this element” instead of “as this element”.

We have used “because this element” instead of “as this element”.

Line 252: Well, this is not exact. The element from Yicheng samples that showed the highest  $\Delta f(\alpha)$  values was Zn, according to table 2.

We have updated this and now use three multifractal parameters together to discuss the results of our study.

Line 253: Remove “showing the distribution of Pb in the Daxing area and Hg in the Yicheng area” since it is already said in the former sentence.

We have removed “showing the distribution of Pb in the Daxing area and Hg in the Yicheng area” from the sentence.

Lines 255-279: This portion of text is a very poor discussion of your results. You did not discuss anything about Daxing contamination. It is also funny that you talk about Hg contamination in Yicheng but the concentrations of this element were greater in the samples of Daxing (see table 1). I am also not sure about the need of performing a multifractal analysis for obtaining these results; a simple geostatistical approach would be enough.

We have added Table 3 and Fig. 5 as well as associated text to enhance our discussion of our results, including comparing the differences between the results of purely statistical summaries and multifractal analysis. Our study indicates that multifractal modeling and the associated generation of multifractal parameters is a useful approach for the evaluation of heavy metal pollution in soils and the identification of major sources of heavy metal contamination.

Lines 283-286: Please, re-phrase this caption, it is not clear.

C13

We have rephrased and simplified this caption to make it more clear.

Lines 289-291: I would change the caption of this figure to “Filled contour map obtained by inverse distance weighted interpolation showing the spatial distribution of soil Pb concentrations in the Daxing area”.

We thank the reviewer for their suggestion and have amended the caption for Fig. 4 appropriately.

Lines 294-296: I would modify the caption of this figure to “Filled contour map obtained by inverse distance weighted interpolation showing the spatial distribution of soil Hg concentrations in the Yicheng area”.

We have changed the caption of Fig. 5.

Lines 299-302: I would change the caption of this figure to “Filled contour map obtained by inverse distance weighted interpolation showing the spatial distribution of soil Cu concentrations and the location of breeding facilities in the Yicheng area”.

We have changed the caption of Fig. 6.

Conclusions:

Line 306: Include “the latter” after “although”.

We have included “the latter” after “although”.

Line 307: Remove “for the soil geochemical data”.

We have removed these words.

Line 309: Remove the word “value” before “changes”.

We have removed the word “value” before “ranges”.

Line 310: There is a mistake here; according to table 2, the  $\Delta f(\alpha)$  in Yicheng decreased as Zn>Hg>As>Cd>Pb>Cu instead of Hg>Zn>As>Cd>Pb>Cu as is reported here.

C14

We have updated the conclusions to include this.

Lines 314-319: However, the Hg concentrations in soils from the Daxing area were greater than in Yicheng.

We have updated the conclusions to include this.

Lines 320-326: I am not sure about this conclusion. Further explanations are needed in the discussion section to state this.

We have rewritten the conclusions to make them more clear and to reflect our enlarged discussion section.

References:

Line 343: Use the full name of the journal; in this case it should be "Computers and Geosciences" instead of "Comput. Geosci."

We have used the full name of the journal.

Lines 346-347: It should be spelled with a capital letter: "University of Geosciences".

We have revised this to use a capital letter.

Line 353: It should be spelled with a capital letter: "Journal of Hazardous Materials"

We have revised this to use a capital letter.

We thank Drs Miras-Avalos, J. Miranda and an anonymous referee for their positive comments and have improved the written English and revised the confusing sentences within our paper. Please find the revised manuscript in supplement. We hope that this manuscript is now acceptable for publication with the corrections and edits noted above. Please do not hesitate to contact me if you need any more information on or clarification of these revisions.

Yours faithfully,

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Feng Yuan

Please also note the supplement to this comment:

<http://www.nonlin-processes-geophys-discuss.net/npg-2016-15/npg-2016-15-AC3-supplement.pdf>

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Interactive comment on Nonlin. Processes Geophys. Discuss., doi:10.5194/npg-2016-15, 2016.

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