Referees Comments on the NBRP Position Paper and Responses by the NBRP team

Referee 1

Comment 1: The position paper is a novel approach to determination of limits from land applied biosolids. In this approach, maximum permitted total Cd, Cu, or Zn loadings from biosolids are based on soil properties correlated with risk-based endpoints. I applaud the authors for use of an indirect measure of metal bioavailability (i.e., soil properties) to set metal loading limits in soil.

Response 1: No response is required.

Comment 2: However, there is an essential component missing. Namely, the properties of the biosolids that may limit metal solubility / bioavailability and risk from biosolids-borne metals is not part of the framework. The authors have shown similar results between biosolids in this study and metal salt-treated soil for Cd (McLaughlin et al., 2006) but results for Cu and Zn may exhibit different behavior.

Response to comment 2: The issue of the effect of biosolids matrix on the solubility and bioavailability of Cu and Zn has been addressed in the study. This is discussed in detail in the technical document by Heemsbergen et al. (in prep b).

Comment 3: The effect of Fe oxides on sorption of Cu and Zn are well-known. Biosolids can contain significant iron oxides formed from use of Fe salts during wastewater treatment. High Fe biosolids have been shown to have much lower bioavailability of cationic metals including Cd (Hettiarachchi et al., 2006). Sorption capacity of biosolids for metals has been attributed to either reactive Fe oxides or stable organic matter fractions (Sukkariyah et al., 2005). Metal soil bioavailability is often lower in biosolids-treated soil than metal salt treated soil. The higher availability of metal salt in soil, termed the salt effect, is well documented (Basta et al., 2005).

Response to comment 3: The experimental design of the NBRP was specifically designed to assess this issue. The paper of McLaughlin et al. (2006) clearly showed that the Cd in the biosolids in this study did not exhibit reduced solubility compared to Cd salts – see Figures 1 and 2 in that paper. The issue of metal retention by biosolids is the subject of continuing research by Whatmuff et al. and these data will be published in 2008/9.

Comment 4: However, McLaughlin et al. (2006) shows Cd from biosolids had similar bioavailability as Cd salt. This finding is the basis of not focusing on biosolids properties in the position paper. I agree with the conclusion of the well designed study of McLaughlin et al. (2006), but believe more explanation should be provided for not considering biosolids sorption properties in the position paper. I suggest (i) a more detailed analysis of the biosolids in the study be provided (including reactive Fe content) in the position paper, and (ii) more discussion be added on the equivalent of metal bioavailability in biosolids vs. metal-spiked soils.

Response to comment 4: See response to Comment 3. We agree on the importance of the relative bioavailability of metals in metal-spiked soils and biosolids-amended soils. However, we do not agree that this should be in the Position Paper. This is a level of technical detail not warranted in the Position Paper – rather

we have examined this issue in detail in a technical document (Heemsbergen et al., in prep b) that accompanies the Position Paper.

Comment 5: Even if there are differences between biosolids and metal salts, it is possible to state higher bioavailability metal salt data was used to produce a more conservative risk-based regulation.

Response to comment 5: This is certainly one possible approach. However, this assumes that the availability of metals from biosolids can not be greater than that from metals salts. We preferred to actually determine the relative bioavailability of metals from biosolids and from metal-salts rather than making assumptions. We believe that our approach is scientifically rigorous and consistent with the risk paradigm.

Comment 6: Similarly, biosolids properties (i.e, reactive Fe and Al oxides) have been shown to decrease solubility and availability of biosolids-borne phosphorus (Elliott et al., 2002; O'Connor et al., 2004). Use of water-extractable P tests have been recommended to evaluate the effect of Fe and Al oxides in biosolids instead of using total P in biosolids and manures (Kleinman et al., 2007).

Response to comment 6: The principle focus of the Position Paper is to recommend new guidelines for metal contaminants in biosolids amended soils. The focus is not nutrients. Having said this, the best way to measure the bioavailable P is to measure uptake into plants using field-trials – this is the approach that was undertaken by the NBRP.

Literature Cited

Basta, N.T., J.A. Ryan, and R. L. Chaney. 2005. Trace element chemistry in residual-treated soil: Key concepts and metal bioavailability. *J. Environ. Qual.* 34: 49-63.

Elliott, H.A., G.A. O'Connor, and S. Britton. 2002. Phosphorus leaching from biosolids-amended sandy soils. J. Environ. Qual. 31 :681-689.

Hettiarachchi, G.M., J.A. Ryan, R.L. Chaney, and C.M. La Fleur. 2006. Sorption and desorption of cadmium by different fractions of biosolids-amended soils. J. Environ. Qual. 32 :1684-1693.

Kleinman, P., D. Sullivan, A. Wolf, R. Brandt, Z. Dou, H. Elliott, J. Kovar, A. Leytem, R. Maguire, P. Moore, L. Saporito, A. Sharpley, A. Shober, T. Sims, J. Toth, G. Toor, H. Zhang, and T. Zhang. 2007. Selection of a water-extractable phosphorus test for manures and biosolids as an indicator of runoff loss potential. J. Environ. Qual. 36 :1357-1367.

McLaughlin, M.J., Whatmuff, M., Warne, M.St.J., Heemsbergen, D., Barry, G., Bell, M., Nash, D., Pritchard, D., 2006. A field investigation of solubility and food chain accumulation of biosolid-cadmium across diverse soil types. Environmental Chemistry 3: 428-432.

O'Connor, G. A., D. Sarkar, S.R. Brinton, H.A. Elliott, and F.G. Martin. 2004. Phytoavailability of biosolids phosphorus. J. Environ. Qual. 33 :703-712.

Sukkariyah, B.F., G. Evanylo, L. Zelazny, and R.L. Chaney. 2005. Cadmium, copper, nickel, and zinc availbility in a biosolids-amended piedmont soil years after application. J. Environ. Qual. 34:2255-2262.

Referee 2

Comment 7: I am happy to have the opportunity to provide comments on your draft position paper of the Australian National Biosolids Guidelines for metal contaminants. I found the logic in developing the short-list of metals that warrant regulation, and the approach to soil metal loading limits based on the multiple endpoints of crop quality, phytotoxicity and soil biological processes, to be well-founded. I agree with the selection of copper, zinc and cadmium as the metals most likely to be limiting for agricultural land application. I would caution, however, that molybdenum (Mo) must also be dealt with at some point if the protected agricultural systems include livestock. There is also the smaller, but perhaps not negligible, risk that less common metal pollutants could occasionally be at unusual concentration in specific biosolids generated at particular treatment plants, based on our experience.

Response to comment 7: Molybdenum (Mo) was not included in the set of metals studied by the NBRP. The available literature suggests that Mo is only likely to cause problems if its concentrations in biosolids is high, the biosolids are applied to alkaline soils and livestock graze the biosolids-amended soil. The issue of Mo in biosolids is something that regulators and the water industry may wish to consider in the future.

Comment 8: The recommended limits derived for Cu, Zn and Cd in this position paper are generally consistent with recommendations we have been making at ……, based on published literature and our own experimental results. We did not, however, have the depth of results that came out of your multi-site NBRP, and I am therefore pleased to see the degree of agreement between your suggested soil metal thresholds and ours. Interestingly, the NBRP results show a stronger dependence of bioavailability and/or toxicity of the metals on soil properties (pH, texture, organic matter content) than we had estimated or assumed. The results also show a perhaps-unexpected result (for some scientists in the USA), that biosolids do not provide a protective adsorptive effect, at least for Zn and Cd. The lower solubility of Cu in biosolids-amended soils compared to Cu salt-amended soils is probably the result of strong binding of Cu to organic matter, but this cannot be regarded as permanent. The results also seem to provide a convincing argument for the validity of using "metal-spiked" soils as proxies for biosolids-amended soils, as long as the metal-treated soils are allowed to age. Nevertheless, if this position paper were being reviewed by a number of scientists in North America, particularly those involved with developing the USEPA 503 Rule on biosolids metals in soils, there would be strong criticism on the use of "metal-spiked" soils in developing the metal thresholds. I think your research has clearly shown, however, that the use of metal-spiked soils, properly aged, is justified.

Response to comment 8: The issue of non-permanent binding of Cu by organic matter has been addressed in a paper by Oliver et al. (2005). This examined the availability of Cu in soils with and without biosolids. They reported that “the available Cu concentration remained relatively low and stable over the 7-yr incubation. This was despite substantial reductions in OC.”

On the issue of metal-spiked soils being proxies for biosolids-amended soils – we do not believe that metal salts can be used solely as a proxy for metals in biosolids. They can however, be used as a proxy provided that parallel tests are run using biosolids, as was done in the NBRP, to permit the relative bioavailability of metals from metal

salts and from biosolids to be evaluated and taken into account in deriving recommended limits for biosolids-amended soils. The material in the technical documents indicates that the food-chain transfer of Cd is likely to be affected by the Zn concentration. Also these show that the relative food chain transfer of Cd from metal salts and biosolids varied by a factor of between 2 and 9. Copper also was shown to have a different bioavailability in biosolids compared to when present as a metal salt. The differences for Cu ranged from 1.2 to 2.15 fold. Thus, for Cd and Cu, metal salts are not good proxies of the same metals in biosolids, whereas for Zn, metal salts appear to be good proxies of Zn in biosolids.

Comment 9: In reading through the supporting technical papers, I believe that the experimental evidence provides a strong basis for the recommended metal limits. In summary, I want to commend you and the research group in Australia for developing these metal limits in a logical and scientifically sound manner.
Response to comment 9: No response required.

Referee 3

Exec. Summary
Comment 10: This is well set out and easily understandable. Perhaps including one line in regard to the preliminary hazard assessment would be useful (2nd para.), it will outline why you picked Cu, Zn and Cd and not Ni, Hg or other metals.
Response to comment 10: A sentence addressing this was inserted at the beginning of the paragraph referred to.

Comment 11: Also in the 2nd para. there is mention of the soluble salt forms of the metals you used in parallel with the biosolid applications. The set up of these experiments is explained on page 8 and again on page 10, but what is not clear is why or how you used these data. It would be appropriate to have a couple of lines on the role these plots had in the derivation of the values you come up with. Maybe in the improvements section?
Response to comment 11: A sentence was inserted into the second paragraph to address this.

Comment 12: Page 3, 3rd para. The text suggests that you add tonnages of material to soil based on the 'added' soil limits. This is in relation to starting from an ambient metal background level in the soils, in the …. – and it may not be the same in Aus. soils can receive organic material from a number of sources (composts, paper pulps, manures, etc.). Therefore, your soil may already be well on its way to the limit before receiving the 'added' biosolid, is this mentioned in guidance or protocols for applications to land? I presume the soil metal concentrations are determined before you can apply biosolids otherwise how would you know what to add your limit to?
Response to comment 12: This is a good point. The recommended limits for Cu and Zn are based on added metal. The final guidelines are obtained by adding the background concentration or an estimate of the background concentration to the added metal limit. As each site will have its own unique background concentration it is not possible to give a set of limits for Cu and Zn based on total concentrations. Text clarifying how the final limits are derived has been added to the Position Paper.

Additional text stating the recommended method of determining the background concentration at a site will be added to the final version of the Position Paper. Text outlining what additional soil properties should be measured if the recommended framework is used and indicative costs will also be added to the final version of the Position Paper.

Background

Comment 13: 2nd para. This section seems to be chronologically at odds with the 'preliminary hazard assessment' section. The latter gives the reasoning as to why Cd, Cu and Zn were chosen, and the former tells us they have already been chosen.

Response to comment 13: The text on the hazard assessment has been moved into the background section and merged.

Comment 14: Page 6, 1st and 2nd paras. It might be worth just stating here (as you mention later on page 13) that its human health for Cd and environmental concerns for Cu and Zn.

Response to comment 14: This has been addressed.

Preliminary hazard assessment

Comment 15: 1st para. This is very useful – the biosolid data used in this exercise was Australian and from all states?

Response to comment 15: This has been addressed.

Comment 16: Table 1. this is a 'relative' ranking of the hazard?

Response to comment 16: The term ranking infers a relative position, so this term has not been amended.

General methods

Comment 17: 4th para. This represents good agricultural practice usually followed in all states?

Response to comment 17: This is sufficiently well known by the target audience for the Position Paper that it does not require clarification.

Comment 18: Table 2, page 9. Climatic conditions are mentioned a couple of times in the text (pages 11, 15, 16……) is it worth having an extra column in here just to say what they are at the trial sites, or will all people know?

Response to comment 18: This has been addressed by indicating which sites below to each of the climatic conditions that are mentioned in the first paragraph after Figure 1.

Comment 19: Table 3, page 10. In the 'biosolids source' column is Bolivar AAD and BDB a source or a type? Similarly Bondi cake – which sounds delightful, but probably isn't.

Response to comment 19: The terms referred to have been removed from the table.

Comment 20: Page 10, 1st para. 'rates of Cd were added to the soils' as salts and sludge or both?

Response to comment 20: This has been clarified by inserting ‘salts’.

Recommended improvements.……..

Comment 21: Page13, 3rd para. this is in the biosolid amended soils?

Response to comment 21: The text appears understandable and correct – so no modification was made.

Comment 22: Page 13, 4th para. Will your audience know what substrate induced respiration means in terms of the implications for soil biology/fertility? Perhaps a line of why this is important?

Response to comment 22: The importance of this and substrate induced nitrification was addressed by adding a sentence to the methods section where these two endpoints are first mentioned.

Comment 23: Table 6, page 14. These are effectively ‘added risk’ values – there will normally follow a question on how to calculate or establish the ABC – I presume it is in one of the appended papers or Rebecca’s work?

Response to comment 23: Yes these are added values and yes the method for calculating the ambient background concentration is described in the technical papers. However, in the final version of the Position Paper (not the version that is available for comment) a section on how the ambient background concentration can be calculated will be added to the Position Paper.

Implications of accepting.……..…

Comment 24: Table 8, page 18. This is using the data from Tables 2 and 3 – I’d put that at the btm of the table – Indeed, I’d suggest having a simplified calculation above the Table demonstrating how this is being undertaken. Practioners over here like it spelled out rather explicitly!

Response to comment 24: The calculations are not simple – so we have not included them. However, we have modified Table 8 to make it simpler to understand and have improved the caption so that it is clear how the values were obtained.

Comment 25: The mass of the biosolid application is clearly limited by how much Zn is in the biosolid. How typical were the metal concentrations in these sludges compared to previous surveys (Luggage Pt. seems elevated compared to Ian Oliver’s work?).

Response to comment 25: The biosolids used in the NBRP are sludges that are generated by active WWTPs. They should therefore be representative of biosolids generated throughout Australia.

Referee 4

Comment 26: It generally reads very well. The executive summary might be shortened by putting paragraph 2 data in a Table (the limits).

Response to comment 26: Doing the suggested modification would have little effect on the length of the Executive Summary. Therefore we did not address this.

Comment 27: Executive summary, paragraph 7: motivate better why you recommend to keep on monitoring soil&plant metals, after all this work it seems that the data are not good enough to derive safe limits.
Response to comment 27: Additional text has been added to clarify under what circumstances this suggestion is required.

Comment 28: Table 2: add a column which sites have been applied with biosolids and metal salts.
Response to comment 28: We do not see the relevance of adding this information to the table and therefore have not addressed this comment.

Comment 29: A conceptual scheme of the derivation of limits would be very welcome here. Think of 1-2 graphs to show the flow of information, e.g. a dose-response curve for salts and sludge, deriving safe values based on salts studies and explaining how soil type dependent values were derived. What regulators want to see is where you draw the line, i.e. ECy and HCx, with y and x values that are important for regulators ('what do the numbers mean').
Response to comment 29: This is a good suggestion and we will do this in the final version of the Position Paper. The figures will be based on those used in the Final NBRP presentations recently delivered around Australia.

Comment 30: The derivation of limits can be debated for ages and I also have some concerns (see below). It is probably not that problematic after all, but that needs to be show with data (now only limits are shown here). I strongly suggest you showing data in the position paper as well, data are equally important for regulators as the 'x and y' concepts above. A graph which helps in the discussion (as I experienced) is the limits versus the effects found in the field. Think about adding an aggregated dose-response graph per metal (soil metal in X-axis; effects data in Y-axis), but only for data of biosolid amended soils, no metal salts. The limit (vertical line) should reveal very little effects below the line, whereas some effects possible above the line. Effects data could be % inhibition to control (a stimulation of SIR by sludge would be a negative value) or the plant metal concentration relative to the limit. Of course, there are several vertical lines (pH/OC/Clay dependent), perhaps sites can be dived in 3 classes for which equal limits apply (within boundaries) and data points should be labeled per class.
Response to comment 30: This is a good suggestion however, we are trying to keep the Position Paper simple and succinct and the supporting technical documentation in the technical "backup" documents. Therefore we propose to address this in the final version of the technical documents - Heemsbergen et al., (in prep a) and Warne et al. (in prep a). The modifications to address this have not been included in the version available for comment. Showing effects data for biosolids treatments against soil metal concentrations would not be worthwhile, as the rates of biosolids used were low and metal concentrations in soil never reached effect levels - the biosolid treatments were not designed to test cumulative metal loadings, the metal salt treatments were designed to do this. From the effect levels derived from the metal salt treatments, the maximum cumulative loading of biosolid metals can be determined, and these are well below the rates used in the NBRP.

Comment 31: Typo on section starting with 'recommended improvements…' line, 5: though should be through.
Response to comment 31: Addressed.

Comment 32: Table 8: add details for which sludge metal concentration this calculation was made. Hectare (ha) not with capital)
Response to comment 32: Both of the issues in this comment have been addressed.

Comment 33: It was quite difficult to find the methodology on both the position paper and the technical notes. Clarify the methodology in both documents if, as I suspect, you only used the salt toxicity tests to identify the ECx values in the field. The limits are only calculated from salt tests (correct?) with the exception of the bio-availability factor for Cu (Oliver's pH dependent factors). It would be very helpful to add a conceptual scheme in both documents. In the technical note of Diane, there is Fig. 1, however that does not explain which data are used from the project to identify the various parameters.
Response to comment 33: The detailed methodology used to derive the recommended limits was deliberately left out of the Position Paper and we do not believe it should be added. The methodology is clearly stated in two technical documents which were very clearly titled to indicate the material that they contained. These are set out below:

Heemsbergen DA, Warne MStJ, McLaughlin MJ, Whatmuff M, Barry G, Bell M, Nash D, Pritchard D, Penney N. *In prep a*. A new framework for deriving guidelines for soil and soil amendments: Application to Cu and Zn phytotoxicity data for Australian soils and biosolids.

Warne MStJ, Broos K, Heemsbergen DA and McLaughlin MJ. *In prep a.* Technical Note: Rationale and methods for deriving the microbial toxicity based soil and biosolids quality guidelines.

The referee is incorrect about how the recommended limits were calculated. Metals salts were used to derive recommended soil limits then the relative bioavailability of the metals in biosolids compared to that is metal salts was used to calculate the recommended limits for biosolids amended soils. For Zn the relative bioavailability was the same – so in essence the recommended guidelines are based solely on metal salt toxicity data. However, this was not the case for Cu and Cd where the relative bioavailability differed and therefore the recommended limits are based on both the metals in biosolids. This is made clear in the technical document that compares the relative bioavailability (Heemsbergen et al. in prep b) and the technical documents related to the derivation of guidelines for plants and microbes (i.e. Heemsbergen et al. in prep a and Warne et al. in prep a).

We have previously agreed to include flowcharts in the Position Paper. And improved flow charts will be placed in the final technical documents related to guideline derivation.

Comment 34: In the technical notes, it should then be summarized which final assumptions were then made. As I see it, for plants you used an SSD with all species with a normalization equation established for one species. For microbial processes, the situation is not very clear to me (I did not go to the details), but the abstract of the Technical note made by you should state what you did. I got the impression that SSD is used (option 5), however with only 2 endpoints one cannot calculated an SSD at the same time as normalizing the toxicity data. If it is true that you calculated an HC20 that is then back-calculated to a soil specific limit, I disagree with the method because you used the data twice (nomalisation& SSD), the formulation that 'the limit protects 80% of the sites from effects on SIR' is not applicable to the site specific limits, it only applies to the generic (not-normalised) value.
Response to comment 34: Key assumptions associated with the derivation of the recommended limits will be added to the final version of the technical documents related to the derivation process.

The issue of how the microbial limits were derived – The referee did not correctly understand the method used to derive the recommended microbial limits. This has subsequently been explained to them and they are now happy with the methodology used – subject to it providing an adequate level of protection. This is an issue we have already agreed to address in the final version of the technical documents on guideline derivation.

Comment 35: The bioavailability factor sludge-salt is probably a safe (conservative) value, however it is only based on E value, not on toxicity data. However, that might generally be overcome by my point 5 above.
Response to comment 35: We have agreed to address this issue in the technical documents related to the derivation of the guidelines.

Referee 5

Comment 37: Thanks for sending through the documents – I have primarily focused on the position paper and the 'big picture issues' rather than the underlying technical reports, since I have had limited involvement in recent years. I know I said yesterday that I didn't think I had many comments, but when I wrote them out there are quite a few. The comments follow below, but note that I have mixed in the minor comments (eg some suggested clarification) and the more significant comments as I have followed the order of the document:
Response to comment 37: No response required.

Comment 38: The outputs from the NBRP are awesome and I think the project is unique in terms of the number of sites involved and common approaches. Therefore, it represents a very significant piece of information and very credible outputs. Possibly there could be some more words in the Exec Summary and Introduction to highlight this point, since demonstrating the credibility is important for adoption – nothing helps like showing this is the cutting edge for scale and integration;
Response to comment 38: Some text along the lines mentioned has been added to the end of the first paragraph of the Executive Summary.

Comment 39: Exec Summ para 1 2nd last sentence – suggests that the research on agronomics is separate from issues of nutrients – this paper focuses on the environmental risks from nutrients, rather than their agronomic benefits?;
Response to comment 39: The sentence has been modified to clarify that the Position Paper is addressing results related to environmental impacts associated with nutrients.

Comment 40: Para 2 – comments that the risks posed by metals in biosolids versus soluble forms was assessed. This is described in the methodologies, but it isn't clear later in the document which data sets were used to derive the recommended guidelines and any associated issues. It would be worthwhile having a brief description of how the data was used in deriving the guidelines and whether the biosolids metals are comparable to salt solutions and if not, what this might mean for the conclusions. I recall the US guidelines assumed biosolids were protective versus salt solutions, but your data was suggesting otherwise;
Response to comment 40: This should be addressed by the inclusion of figures which outline the framework used to derive the recommended limits.

Comment 41: Exec summary para 3 – here and elsewhere there is a reference to the concept of 'added copper or zinc'. I assume that this means the amount of copper or zinc added from biosolids, rather than based on total soil levels. I assume that this approach means that the background metal levels are viewed as a different risk to the load from biosolids, hence the two are separated. However, I think there are practical issues with this approach and focusing on total metals in the soil as a function of soil characteristics is better for practical manaagment (or an improved soil bioavailability measure in the soil) – biosolids management plans will typically only focus on biosolids additions and will occur over prolonged time frames, so it would be difficult to have confidence in control based on ongoing quantification of all inputs and recording total additions of the metal. It would be practical though, to monitor soil levels at intervals eg after 2-3 applications and respond if levels are approaching the triggers;
Response to comment 41: This issue will be clarified through the figures that explain the framework and the text that explains about the ambient background concentrations and how these are to be determined.

Comment 42: Page 2 para 4. Support paragraph, but the data also suggests that there are some sites where very limited applications would be appropriate and it is recommended that some crops are not grown on biosolids amended soils. It might be considered this paragraph is a little to positive and the caveats described?
Response to comment 42: We believe that the paragraph is appropriate and do not propose to change this paragraph.

Comment 43: Final para – might be useful to separate out the concept of N mineralisation and P accumulation into separate paragraphs. It is a little confusing running them into the one paragraph.
Response to comment 43: This has been done.

Comment 44: Intro para 1 – is loss of nutrients via plant uptake the only mechanism or are others significant?
Response to comment 44: This has been addressed by including losses via surface run-off, leaching and binding to soil particles.

Comment 45: Intro para 3- industrial chemicals seems to be a strange term in this context – is 'and other synthetic compounds such as pesticides' a better fit?
Response to comment 45: This phrase has been deleted from the Position Paper.

Comment 46: Intro para 4 – is it worthwhile noting that Australian biosolids guidelines attempted to set conservative soil quality standards, but risk is heavily controlled by soil parameters and therefore a single guideline value is either over protective or under protective depending on the soils involved;
Response to comment 46: This has been addressed.

Comment 47: Background, para 3 – is it worthwhile noting that Cd contamination in soils has primarily been due to phosphatic fertilisers and so there is a cadmium management strategy?
Response to comment 47: While this is true, it is not really relevant to the hazard assessment. So this comment has not been addressed.

Comment 48: Figure 1 – second para down. Would it be better to note that the NLBAR is 'calculated as the predicted' amount of biosolids that can be …. The current text suggests it is an accurate measure, but later data shows otherwise;
Response to comment 48: Addressed.

Comment 49: Table 2 -1st para down, is it normal farmer practise for the site – I assume there wasn't a single generic 'farmer practice';
Response to comment 49: Addressed.

Comment 50: Table 3 – does the AAD and BDB need to be defined?
Response to comment 50: These terms have been deleted from the table along with the term 'cake'.

Comment 51: Final sentence – general methods. Suggest 'Research is ongoing to determine whether refinements to guidelines are also appropriate for management of pathogens and organic contaminants', to replace 'work on risks….
Response to comment 51: Done.

Comment 52: Recommended improvements para 3. The suggested avoidance of high Cd uptake crops appears sensible, but it does present some issues. If land has had biosolids applied, does this mean it should never be subsequently used for these crops. If this requirement is adopted in guidelines, at an extreme this could result in land application management plans including a clause that prohibits changes in farming practice etc. Presumably this would destroy the biosolids market? There probably needs to be some thinking about how this should be incorporated into guideline requirements……

Response to comment 52: Yes this suggestion does have some implications to the land application of biosolids. The recommendation of not using biosolids on land to grow certain crops is consistent with current best management practices in a wide variety of agricultural sectors relating to Cd. The implications of not following this recommendation are that crops may exceed the permissible limits for Cd and will therefore not be saleable either domestically or internationally. It is in the best long term interests of farmers and the biosolids industry that this situation does not arise.

Following our recommendation will certainly limit the areas where biosolids can be applied but by no means will destroy the biosolids market. There are vast tracts of agricultural land which is highly unlikely to be ever used for the mentioned crops. Given this we do not propose to amend the text.

Comment 53:* In regard to cadmium, is it possible to state that managing food chain risks for crops is the limiting pathway ie protecting crop update will protect against meat and kidney accumulation, or are these separate issues that need to be considered;
In regard to copper and zinc, is it possible to state that micro-organism function and plant growth are the most sensitive endpoints from the literature, hence if these endpoints are protected the environment is OK?

Response to comment 53:
Regarding Cd uptake – It is not possible to make such statements.
Regarding the relative sensitivity of plants and micro-organisms – It would be fair to say from the literature that many terrestrial invertebrates are more tolerant of metal concentrations in soils than plants and bacteria. But it is never possible to make blanket statements as invariably there is an exception or the statement is based on rather limited amounts of data. We chose to test plants and micro-organisms as these two types of organisms are essential to agricultural land. It is important to note that the limits that are being recommended are not designed to protect all terrestrial ecosystems – they are designed to protect agricultural ecosystems.

In the final version of the Position Paper we will clarify exactly what the recommended limits are intending to protect.

Comment 54: Interesting the Substrate induced respiration was not affected by soil properties – is it worth a brief note re whether this is a major issue for the fundamental hypothesis that toxicity is linked to bioavailability and therefore guidelines need to reflect soil properties;

Response to comment 54: In hindsight it is not that surprising that substrate induced respiration was not affected by soil properties. Reasons for this include the fact that all micro-organisms contribute to this measure of respiration with each species having its own unique sensitivity to the metals. Thus, while some species may be affected at a given metal concentration other species may in fact increase in number and thus there could be no overall effect on substrate induced respiration. Having multiple species able to perform the same function is called functional redundancy. Thus any affect that soil properties may have on the toxicity of metals to the respiration of a particular microbial species is masked by the different tolerances of other microbial species.

The logical place to have addressed this issue was in the paper by Broos et al. (2007), but this has been published. However, it could certainly be added to the technical document Warne et al. (in prep a). This will be done in the final version of this document (not the version available for comment). We do not believe that addressing this issue in the Position Paper is appropriate as we are trying to keep in simple and this issue is a rather technical matter.

Comment 55: Is it worthwhile describing how protective the recommended concentration limits are – at these concentrations are some subtle impacts expected, significant impacts, impacts on sensitive organisms or are they conservative and no micro-organism or plant growth impacts expected;
Response to comment 55: This is a good idea and similar to that expressed by another referee. Careful consideration on exactly how this issue is to be addressed is required. The response to this comment will be included in the final version of the Position Paper.

Comment 56: In regard to the recommended impacts on guidelines, it is worthwhile considering that most Aust guidelines have the C1 / C2 classification system. C2 is straightforward in Vic because there is normally a site specific management plan that is prepared and a site specific soil limit can be established – the guideline just needs to either include the tables or reference this approach. C1 is problematic as it is a grade of biosolids that can be used without restriction due to low metal levels. The C1 limit is typically based on a predicted conservative soil concentration eg 1 mg/kg for Cd, hence the theory is that since the biosolids are below the relevant soil concern level, end use management isn't needed. The key issue that arises from your data is that clearly the current C1 limits and philosophy isn't protective for some soils, therefore either further assessment is required, C1 should be reduced or removed. If C1 is reduced or removed, this will have flow on effects for composts as often regulators have used biosolids guidelines for compost guidelines (which doesn't seem to be appropriate, but is reality). Removing or changing C1 would be significant as there are water businesses currently producing a C1 product as part of their strategy.
Response to comment 56: This is certainly an issue that the biosolids industry and regulators need to consider if they proceed with accepting the recommendations in the Position Paper.

Comment 57: Nutrient recommendations para 1- appears to suggest that metal contaminant availability is not influenced by soil properties, but I think the point is that nutrients are influence by a broader range of issues, with soil properties being just one.
Response to comment 57: This has been clarified by removing the text referring to the metal salts.

Comment 58: Movement to P based guidelines appears to have some basis, but will obviously cause some issues.
Response to comment 58: At this stage the Position Paper merely suggests that PLBARs may be warranted and that if this is the case that a national approach would be warranted. Any issues associated with this suggestion would be best considered once the research was conducted to develop PLBARs.

Comment 59: In preparing the comments, I have assumed that the position paper might be the only document that many people read, hence, important to make sure all the issues are clear.
Response to comment 59: No response required.

Comment 60: Despite what seems like a long list of comments, it is obviously fantastic work and will make a real difference to the confidence in managing schemes.
Response to comment 60: No response required.

References cited

Oliver IW, Hass A, Merrington G, Fine P, McLaughlin MJ. 2005. Copper availability in seven Israeli soils incubated with and without biosolids. J. Environ Qual. 34: 508 – 513.