Lead drier replacement in solvent based alkyd decorative paints

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Background

Exposure to lead causes significant injury to human health and imposes large economic and social costs on developing countries. Children are especially sensitive to lead, and the World Health Organization (WHO) has concluded that no level of lead exposure to children is safe.

Lead in paint is a major source of lead exposure in children. When lead paints are used in homes, schools and elsewhere, childhood lead exposure pathways are created. All paints weather and wear over time. When this happens, lead from lead paint ends up in dust and soil found in and around homes and schools. Large quantities of lead-contaminated dusts are also created when old painted surfaces are scraped and sanded prior to repainting. Children get dust and soil on their hands and then ingest the lead through normal hand to mouth contact. They can also ingest lead through inhalation, by eating flaking paint chips, and by chewing on toys painted with lead paint.

Most highly industrialized countries severely restricted the lead content of paints for sale and use in their countries in the 1970's and 80's, either through maximum allowed limits or prohibition of use of lead-containing paint ingredients. In the U.S, the maximum permitted total limit for lead in decorative paint was recently lowered from 600 to 90 parts per million (ppm), emphasizing the importance of avoiding even low-level exposure.

This report was produced by Safinah Ltd on behalf of IPEN, as part of the Asian Lead Paint Elimination Project funded by the European Union. The Asian Lead Paint Elimination Project was established to eliminate lead in paint and raise widespread awareness among business entrepreneurs and consumers about the adverse human health impacts of lead-based household enamel paints, particularly on the health of children under six years old. The Project was implemented by IPEN over a period of three years (2012-2015) in seven countries (Bangladesh, India, Indonesia, Nepal, Philippines, Sri Lanka, and Thailand). While this report has been produced by Safinah Ltd and with funding from the European Union, its contents are the sole responsibility of IPEN, and can in no way be taken to reflect the views of the European Union or Safinah Ltd.

IPEN is a network of non-government organizations (NGOs) in 116 countries; most of which have developing and emerging economies. IPEN's mission is a world in which chemicals are no longer produced or used in ways that harm human health. IPEN's NGO network identifies important national issues where international policy can help protect people and the environment from toxic chemical exposure and then organizes activities that elevate and prioritize those issues within international policy arenas. Once international policy is established, IPEN mobilizes expert and financial resources to help NGOs and their national governments turn international policies into meaningful, on-the-ground change. The majority of funds IPEN raises are re-granted to NGOs in the developing world. IPEN´s goal is global lead paint elimination by the year 2020.

Contract Report for

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2 INTRODUCTION

1. IPEN is a global network comprised of 700 participating organisations in 116 countries. As an NGO it brings together leading environmental and public health group around the world.

2. Currently IPEN has a European funded initiative to assist developing countries to remove lead from paint formulations.

3. The IPEN Asia lead paint elimination programme aims to eliminate manufacture, import, sale and use of decorative paint containing lead in 7 Asian countries.

4. While larger paint companies have the resource and capability to re-formulate, smaller paint manufactures lack the resource and sometimes the capability/expertise to undertake re-formulation work.

5. The aim of this project is to identify a suitable Paint Chemistry Expert to produce a series of reports and provide advice to assist these companies in developing lead elimination programmes.

6. IPEN has approached Safinah to undertake this project to provide advice in the areas of water based and solvent based decorative coatings.

7. This report deals with the replacement of lead driers in solvent based alkyd paints.

3 SCOPE

3.1 Solvent based one pack decorative paints – guidance on reformulation

1. IPEN understands that the main sources of lead in solvent based one pack decorative paints are:
    i. Driers
    ii. Pigments
2. They understand that there are several routes that can be taken to eliminate lead containing materials and replace them with lead free alternatives. The larger paint companies have good relationships with the major suppliers/manufacturers of the materials, and therefore receive good advice on how to make the changes.

3. Small and medium size paint companies do not have the same technical support through their supply chains as they will often purchase materials from distributors or agents, not the primary manufacturer.

4. IPEN wish to be able to provide guidance to these companies to help identify the offending materials, and how to go about replacing them in a formulation.

5. This guidance to be targeted at smaller paint manufacturers who may not have the capability to reformulate. The guidance should cover:
    a. The steps to be taken when reformulating to avoid lead driers
    b. Possible approaches to cost-effective substitution of lead driers.
    c. Identification of suitable vendors or suppliers of the substitute ingredients. This may prove difficult so the chemical type will be provided as well rather than simply a trade name.

6. This output can be in note form if needed.

7. NOTE: Litharge (lead oxide) has been used in the past as a catalyst in the manufacturing of alkyd resins at levels of approximately 0.5% by weight. This practice has all but died out as litharge has mostly been replaced by more efficient esterification catalysts such as lithium. Consequently, this potential source of lead will not be discussed further in this report. However, it is a potential contributor to total lead levels.

4 DRIERS IN SOLVENT BASED DECORATIVE ALKYD PAINTS

4.1 Basic alkyd resin technology

8. A typical alkyd paint formulation contains the following ingredients:

- Alkyd resin
- Pigments (colouring and extender)
- Additives (wetting agents, thixotropes)
- Driers (for example cobalt, lead, calcium soaps)
- Solvent

9. In very simple terms, alkyd resins are the reaction products of the polycondensation of a polyhydric alcohol (such as pentaerythritol), a polybasic acid (such as phthalic anhydride), modified with a triglyceride oil or fatty acid. The triglyceride oil is an ester of unsaturated C18 fatty acids and glycerol and is generally derived from low cost renewable resource, such as linseed oil, soya bean oil. Alternatively, tall oil fatty acid (TOFA) which is a mixture of C18 unsaturated fatty acids can also be used.

10. Alkyd resins are often referred as oil modified polyesters. Depending on the amount of ‘oil’ in the molecule, they can be sub-divided into long oil (>60% oil length), medium oil (40-60 % oil length) and short oil (<40% oil length) resins. Each of these types requires the use of paint driers to promote film formation and drying.

11. Alkyd resins (or paints) cure by oxidation of the unsaturated fatty acid chain. During film formation, oxygen from the air crosslinks the unsaturated fatty acids by the creation and decomposition of peroxides. The oxygen uptake process is catalysed by certain transition metals and these are the driers which are used in the formulation.

12. Further resin modifications are possible to produce alkyds with enhanced properties, for example urethane or silicone alkyds. The drying process for these modified alkyds is generally the same as that of an unmodified alkyd so the same principles should be followed when replacing lead driers by lower toxicity alternatives.

4.2 Types of drier and their mode of action

13. Driers can be divided into four categories depending on their mode of action:

- ***Primary driers (e.g. cobalt manganese, vanadium)***
  Primary, 'surface' or 'top' driers act as oxidation catalysts, as the metals exhibit more than one oxidation state. Primary driers catalyse cross linking of the resin and in the process hydroxyl, carbonyl and carboxylic groups are formed. By encouraging surface drying, they produce tack-free films very quickly.

- ***Through driers (e.g. lead, zirconium, strontium)***
  Through driers ensure that a coating dries at a uniform rate throughout the body of the film and not just the surface. Without through driers, primary driers would simply skin the surface of the film, whilst the coating underneath would remain wet for a long time.

- ***Auxiliary driers (e.g. Calcium, Barium, Zinc):***
  Auxiliary driers modify the effect of the other driers but do not demonstrate any drying action on their own.

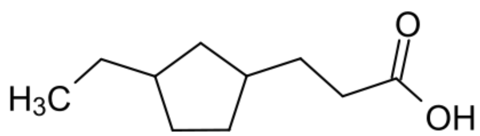
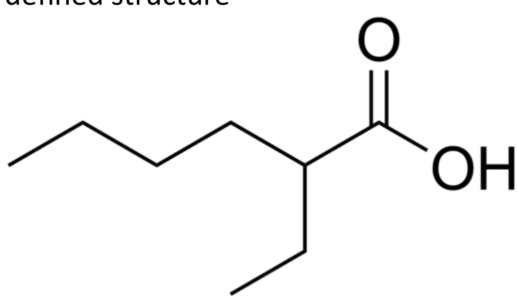
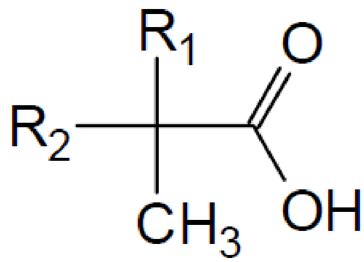
- ***Coordination driers (e.g. aluminium complexes)***
  Coordination driers are used in high acid value alkyds as they promote cross linking through the acid groups on the alkyd rather than by oxidation.

14. Due to their different modes of action, driers are almost always used in combination such as cobalt/calcium/zirconium or cobalt/lead/calcium. The precise ratio of metal contents is adjusted by the paint manufacturer to give the optimum drying performance in terms of top and though drying. Care must be taken to use the minimum amount of drier as addition of too much drier can lead to early embrittlement and discolouration of the film.

4.3 Basic drier technology

15. Driers are the reaction product of a metal or metal compound with an organic acid dissolved in a hydrocarbon solvent such as white spirit. Other solvents can also be used.

16. A number of metal compounds and acids can be used to make driers. Initially, naphthenic acid was used in manufacturing but now, synthetic acids such as 2-ethylhexanoic acid (2EHA) and versatic acids are more common. These acids are often cheaper than naphthenic acid and chemically more consistent. The acid confers solubility on the drier and plays no part in the drying process.

Acid	Common terminology – based on lead metal
Naphthenic acid – a mixture of naturally occurring acids 	Lead naphthenate
2-ethylhexanoic acid – a synthetic acid, defined structure 	Lead octoate Lead bis (2-ethylhexanoate) Lead 2-ethylhexanoate
Versatic acid – highly branched C10 tertiary carboxylic acid mixture. Also known as neodecanoic acid 	Lead versatate Lead neodecanoate

Isononanoic acid 	Lead isononanote
Overbased driers contain synthetic acids such as 2-ethylhexanoic acid and in addition use carbon dioxide in the process to increase metal contents, lower viscosity and reduce acid use.	Lead driers are not made by this route whereas it is possible to make overbased strontium drier. It would be referred to for example as 'overbased strontium octoate'

17. The percentage by weight of metal in the drier is the most important aspect as the metal is the catalyst for the drying reaction.

18. The type of metal and its concentration in weight % (wt%) in the solution, is used to describe the drier. So, if the concentration of cobalt (expressed as metal) is 10% by weight in the drier solution, the drier is generally termed 'cobalt 10' or 'cobalt 10%' without reference to the acid part of the molecule.

19. Similarly, lead driers would be referred to as 'lead 36' or 'lead 36%'.

20. Driers are typically manufactured at high metal contents and then diluted to facilitate handling – specifically accurate dosing - by the end user. So, driers such as cobalt 10% and lead 36% would be diluted with solvent to, for example, cobalt 5% and lead 24%. A paint manufacturer might purchase 'lead 24%' or 'cobalt 5%'.

21. In terms of effectiveness, in general, there is no difference in performance between a lead naphthenate 24% and a lead octoate 24% as it is the lead content which is the active part of the drier molecule.

22. 'Overbased' driers substitute part of the acid in a drier with carbon dioxide during the manufacturing process. This does not affect the way the drier works and an octoate can be substituted by an overbased drier at the same level of metal content in the final resin in the majority of cases. If an overbased drier is used to substitute a typical octoate drier at equivalent metal levels, then the paint company should check that the drying times are unaffected.

23. Driers may be supplied as single metal driers in bulk (200l drums) or smaller containers. This means that a paint manufacturer will carry stocks of each individual drier.

24. Alternatively, since driers are used in combination (see below), they may also be supplied as a 'mixed' or 'combination' driers. 'Mixed' or 'combination' driers are blends of driers in the ratios stipulated by the paint company. This option reduces the number of stock keeping units carried by the paint maker.

4.4 Calculation of the amount of drier required in a formulation

25. The amount of drier needed for any paint formulation is expressed as the percentage by weight of drier metal on the alkyd resin solids (or non-volatile material). This can then scaled up into the amount needed for a specific batch size.

26. Example 1 – Calculation of amount of cobalt 10% drier needed for 1000g of 40% solids alkyd resin solution at 0.05%w/w.

- Drier is cobalt octoate 10%
- 1000g alkyd resin solution at 40% solids (non-volatile)
- Target drier level is 0.05% cobalt w/w on resin solids
- 1000g alkyd resin solution contains 400g solid resin
- Cobalt level required is 0.05% of 400g = 0.2g cobalt metal
- Amount of cobalt 10% solution needed 0.2/10 x 100 = 2g

27. So, 2g of cobalt 10% drier should be added to 1000g alkyd resin solution (40% solids) to provide 0.05% cobalt metal on resin solids.

28. Example 2: Calculation of amount of strontium 24% drier needed for 1000g of 40% solids alkyd resin solution to give 0.25%w/w on resin solids

- Drier is strontium octoate 24%
- 1000g alkyd resin solution at 40% solids (non-volatile)
- Target is 0.25% strontium w/w on resin solids
- 1000g alkyd resin solution contains 400g solid resin
- strontium level required is 0.25% of 400g = 1g strontium metal
- Amount of strontium 24% octoate drier needed is 1/24 x 100 = 4.16g

29. So, 4.16g strontium 24% octoate should be added to 1000g of resin solution to give 0.25% w/w strontium on resin solids.

30. NOTE: When reviewing recommended drier levels in suppliers' literature there is often a range quoted. It is good practice to take the midpoint of the range as a starting point for the paint manufacturer to determine the optimum level required.

4.5 Calculation of the amount of drier for different batch sizes

31. In this case the weight of drier required can be calculated using the following equation:

$$\frac{(\%\ \text{resin solids}) \times (\%\ \text{metal required}) \times \text{batch weight}}{(\%\ \text{Metal of drier solution}) \times 100}$$

32. As an example:

    15000 kg paint of 40% alkyd resin solids, requiring 0.06% strontium on resin solids will require 30 kg of strontium 12%.

4.6 Loss of dry

33. 'Loss of dry' is a phenomenon most often seen in highly pigmented systems, especially those pigmented with carbon black, toluidine blues green and reds and other high surface area organic pigments. It may also be observed in whites and pastel colours but this is relatively uncommon.

34. 'Loss of dry' is seen as an increase in drying times on storage compared to the initial drying time of the paint soon after manufacture.

35. It is caused by the adsorbtion of the active metal drier onto the surface of the pigment, thereby rendering the drier inactive and preventing it taking part in the drying of the paint.

36. Driers such as calcium octoate can be used to minimise or prevent loss of dry by becoming preferentially adsorbed onto the surface of the pigments instead of the active metal drier. In making a paint, it is good practice to add the calcium drier first, before the other driers in order to maximise its effectiveness.

37. An alternative method is to simply add more active drier metal such as cobalt to the initial formulation to offset the subsequent effects of adsorbtion onto the pigments and consequent loss of dry.

5 REPLACEMENT OF LEAD DRIERS

5.1 Background

38. Replacement of lead driers by lower toxicity materials began in the 1970's and a number of alternatives have been proposed over the years. The most effective replacements have been found to be based on strontium and zirconium. Both are successfully used in paint formulations although strontium driers are now considered to have better all-round performance and are less toxic than zirconium driers.

39. Zirconium driers are supplied as octoates, naphthenates and neodecanoates etc at a number of different metal concentrations up to 24% metal.

40. Strontium driers are also supplied with different acid functionalities and at different metal contents as well as in the form of overbased driers.

41. It should be noted that although zirconium compounds are considered to be less toxic than lead, they have nonetheless been found to be more toxic than strontium compounds. It is for this reason that strontium driers should be preferred rather than zirconium driers whenever possible.

42. NOTE: Any substitutions of lead drier by strontium or zirconium driers should be carried out based on the levels of lead drier currently used in the formulation and subsequent testing carried out to ensure that the levels are correct.

43. CAS numbers for the most common zirconium and strontium driers are given below.

    a. Zirconium octoate is 22464-99-9
    b. Zirconium versatate is 39049-04-2
    c. Strontium octoate – 2457-02-5

5.2 Replacement of lead driers by strontium

44. Compared to lead driers, strontium driers are considered to have the following properties:
    - Strontium driers provide excellent "Loss of Dry" properties, equivalent to lead in this respect

- Strontium may be considered a more efficient drier than lead as levels of strontium are generally 33% of that of lead (1 part by weight of Strontium = 3 parts by weight of Lead)
- At a replacement level of 1 part of Strontium to 3 parts of Lead, comparable performance can be achieved in terms of:
    - ✓ Initial drying time
    - ✓ Yellowing
    - ✓ Weathering
    - ✓ In can stability

(Source: Huntsman, Birtley (Formerly Rockwood Chemicals), UK)

45. Price differences between strontium and lead driers are dependent on the base metal costs. However, given the low levels of addition of driers and their relatively low contribution to overall cost structure, the cost of formulations containing strontium driers can be comparable to those formulations containing lead driers.

46. Strontium is generally regarded as the best alternative drier to lead. Huntsman, who manufacture strontium driers, suggest that the following is a good starting point for replacement of lead:

1 part by weight strontium = 3 parts by weight lead

47. So, if a paint formulation contains 0.45% w/w lead based on resin solids, then the replacement strontium drier should be added at 0.15% w/w strontium based on resin solids. All other parts of the formulation, including the rest of the drier package remain the same.

48. In terms of calculating the amount of strontium drier to add, there are two possible scenarios, one where the strontium and lead concentrations in the driers are the same, and another where they are different.

5.2.1 Scenario 1: Lead and strontium driers have the same metal concentration

49. For example, the intention is to replace lead octoate 10% by strontium octoate 10%.

50. In this instance, the required amount of strontium octoate 10% is determined by dividing by three the weight of lead octoate 10% in the paint formulation.

51. So, if the formulation contains 60g lead octoate 10%, this should be replaced by 20g strontium octoate 10%.

5.2.2 Scenario 2: Lead and strontium driers have different metal concentrations

52. There may be situations where the driers in question are supplied at different metal contents, for example strontium 12% replacing lead 24% in a paint formulation.

53. In this case, the following calculation can be used:

  1. Percentage by weight of lead drier present in the formulation: Y_L
  2. Metal concentration (%) of lead in drier as supplied: C_L
  3. Actual Lead content present in the formulation: $Y_L \times C_L$
  4. Target level of strontium required in the formulation: $(Y_L \times C_L) / 3$
  5. Metal concentration (%) of Strontium in drier as supplied: C_S
  6. Percentage by weight of strontium drier to be added in the formulation: Y_S

$$Y_S = (Y_L \times C_L) / (3 \times C_S)$$

54. So, in the case where there is 1% w/w lead 24% in the paint formulation, and the requirement is to replace with strontium 12% (bearing in mind that the strontium level should be 1/3 that of lead), the calculation becomes:

$Ys = (1 \times 24) / (3 \times 12) = 0.66\%$

55. Percentage of strontium 12% to add to the formulation is 0.66% by weight.

5.3 Replacement of lead by zirconium driers

56. Situations may arise where strontium driers are not readily available and there may be a need to replace lead by zirconium driers.

57. Compared to lead driers, zirconium driers are considered to be:
    - Less toxic than lead. Zirconium was the first identified alternative to lead
    - Not as effective as lead driers on a weight to weight basis. Recommended levels of substitution are 3 parts zirconium metal to replace 4 parts of lead metal.
    - Zirconium driers do not prevent "Loss of Dry" and additional calcium drier or a cobalt 'feeder drier' may be needed to maintain drying times after storage. Amines may need to be used to aid the in-can storage stability but this is not common.

58. A cobalt feeder drier is a dispersion of insoluble cobalt hydroxide in cobalt octoate generally in a hydrocarbon solvent such as white spirit. These materials are added at low levels to the formulation. The cobalt hydroxide is slowly dissolved into the system thereby replacing the cobalt drier which is being adsorbed onto the pigment. Drying times can therefore be maintained.

59. The starting point recommendation for replacement of lead by zirconium is as follows (OM Group website):

60. 3 parts by weight of zirconium metal replace 4 parts by weight of lead metal in the formulation.

61. So, if a paint formulation contains 0.40% w/w lead, based on resin solids, then the replacement zirconium should be added at 0.30% w/w based on resin solids.

62. NOTE: Unlike replacement by strontium, it may be necessary to adjust the remaining drier package to maintain performance, in particular for loss of dry.

63. The recommendation, therefore, is to consider increasing the level of calcium drier.

64. The calcium drier is preferentially adsorbed onto the pigment preventing adsorbtion of other driers and consequently minimising loss of dry. The level of calcium is best determined by experiment but addition of an extra 0.05% on resin solids is considered a good starting point.

65. As with strontium driers, zirconium driers are supplied in a range of metal contents and the calculations used in previous sections can be used to determine the amount of zirconium required for a formulation.

5.3.1 Scenario 1: Lead and zirconium driers have the same metal concentration

66. For example, replacing lead octoate 24% by zirconium octoate 24%.

67. In this instance, the required amount of zirconium octoate 24% is determined by multiplying the weight of lead octoate 24% in the paint formulation by 0.75.

68. So, if the formulation contains 60g lead octoate 24%, this should be replaced by 45g zirconium octoate 24%.

5.3.2 Scenario 2: Lead and zirconium driers have different metal concentrations

69. There may be situations where the driers in question are supplied at different metal contents, for example zirconium 12% replacing lead 24% in a paint formulation.

70. In this case, the following calculation can be used:

Percentage by weight of lead drier present in the formulation: Y_L
Metal concentration (%) of lead in drier as supplied: C_L
Actual Lead content present in the formulation: $Y_L \times C_L$
Target level of zirconium required in the formulation: $(Y_L \times C_L) / 3$
Metal concentration (%) of Strontium in drier as supplied: C_S
Percentage by weight of zirconium drier to be added in the formulation: Y_S

$$Y_S = (Y_L \times C_L) / (3 \times C_S)$$

71. So, in the case where there is 1% w/w lead 24% in the paint formulation, and the requirement is to replace with zirconium 12% (bearing in mind that the strontium level should be 0.75 that of lead), the calculation becomes:

$Ys = (3 \times 1 \times 24) / (4 \times 12) = 1.50\%$

72. Percentage of zirconium 12% to add to the formulation is 1.50%

5.4 Replacement of lead in mixed or combination driers

73. Driers are sometimes supplied pre-mixed in the metal ratios required or specified by the paint manufacturer. This helps to minimise stock keeping units and can also make dosing out of the driers simpler and more accurate.

74. A typical mixed drier might contain cobalt at 1%, lead at 10% and calcium at 5% by weight of metal on the mixed drier.

75. Replacing the lead in this mixed drier formulation by **strontium** would require a strontium level of 3.33% w/w on the mixed drier (one part by weight of strontium replaces 3 parts lead).

76. The remainder of the drier would remain the same making the levels of metals: Cobalt 1%, strontium 3.33%, calcium 5%.

77. Replacing the lead by **zirconium** would require the zirconium level to be 7.5% on the mixed drier (3 parts by weight zirconium replace 4 parts lead). At the same time it may be that the calcium level needs to be increased and this may then become 5.5%.

78. So this mixed drier would have the following metal levels: cobalt 1%, zirconium 7.5%, calcium 5.5%.

79. NOTE: The suggested increase in calcium level should only be regarded as a starting point, the optimum level should be determined by practical laboratory testing.

5.5 Assessing the effect on drying of a change in drier formulation

80. It is normal practice to check the effect on drying of any change in drier levels or types. It should be appreciated however, that when driers are added to a paint, they need time to equilibrate. If the drying times are assessed after only a few hours, they will appear long compared to paint that is say 1 day or 1 week old.

81. It is important therefore to evaluate any changes in side by side testing where both old and new drier combinations have been in the paint for the same length of time otherwise results will be misleading. In practice, checking drying times 24hrs after the driers have been added to the paint is generally sufficiently accurate.

82. It is not anticipated that substitution of lead by strontium will lead to any difficulties other than possibly having to optimise the level for drying times.

83. In the case of replacement by zirconium, it would be sensible to treat the suggested replacement level as a starting point and to optimise if needed for drying. Checking performance after storage would confirm if additional calcium drier was required to prevent loss of dry.

6 SUMMARY AND CONCLUSIONS

84. Substitution of lead driers in solvent borne alkyd paints by either strontium or zirconium driers without compromising performance is technically feasible.

85. **Replacement by strontium** is carried out by replacing 3 parts of lead metal by one part of strontium metal by weight in the formulation. Other than the possibility of some optimisation work, no other changes would be anticipated to the drier package or to the formulation as a whole.

86. **Replacement by zirconium** is carried out by replacing 4 parts of the lead by 3 parts of the zirconium metal by weight in the formulation. In addition to optimisation of the zirconium level, it may be necessary to increase the level of calcium drier in the formulation to offset potential loss of dry. Other than this, no other changes to the formulation are likely to be needed.

87. The viability of any changes should be confirmed by carrying out practical drying times after at least 24 hours after the driers have been added to the paint.

88. In the case of replacement by zirconium, drying performance should also be assessed after an extended storage period of 1 and 3 months to check for loss of dry. Adjustments to the calcium level, the incorporation of a cobalt feeder drier or the addition of more cobalt drier initially may be required to offset any loss of dry that occurs.

89. NOTE: Litharge (lead oxide) has been used as a catalyst at levels of approximately 0.5% by weight in the manufacturing of alkyd resins. In the vast majority of cases – perhaps all - litharge has been replaced by less toxic, more efficient esterification catalysts such as lithium.

90. This is a potential contributor to total lead levels in alkyd paints and it is recommended that paint manufacturers confirm whether lead is used as a catalyst with their resin suppliers.

7 RAW MATERIAL MANUFACTURERS

91. A non-exhaustive list of drier manufacturers is given below:

Dura Chemical Corporation Ltd
Wakefield House
11 Shri Shivsagar Ram Gulam Marg,
Ballard Estate,
Mumbai 400 001.
Tel: +91 22 22650861
Fax: +91 22 22617352

Maldeep catalysts pvt India
Mr. P.N. Patel
Harikunj, SVP Road No.3, Surat - 395 003, Gujarat, India
Tel: +(91)-(261)-2278333
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Matrix Universal India
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Tel: +91 9765 486 789
Tel: +91 8551 980 888

PAU THAI INDUSTRIAL (THAILAND) COMPANY LTD

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7.1 Search Engine

92. Drier manufacturers can also be found using the following website: www.ulprospector.com/