COMMUNITY HEALTH EFFECTS RELATED TO EXPOSURES FROM CREOSOTE AND/OR CCA WOOD TREATMENT PLANTS

Dr. A. P. Ryan

MBBCh, DTM&H, DOH, AFOM(UK)

Department of Occupational and Environmental Health

Nelson R. Mandela School of Medicine

Postal Address: Private Bag 7, Congella, 4013, South Africa

Telephone: (+27) 31 260 4471 **Fax**: (+27) 31 260 4663 **Email**: coeh@ukzn.ac.za **Website**: www.coeh.ukzn.ac.za

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Summary

Treatment of wood in South Africa, particularly for use in construction-related applications, currently entails the use of a range of potentially hazardous chemicals. The South African Wood Preservers Association (SAWPA) has undertaken to develop industry standards and guidelines to minimize the risk of exposure of treatment plant workers and environments to these chemicals.

A situation at a specific treatment plant, in which members of a nearby community allege health complaints from exposure to chemicals used in the plant, raises the issue of environmental health concerns, and the potential for wood treatment plants to affect the health of surrounding communities.

The treatment plant in question is situated close to the ocean, in the vicinity of a residential/holiday area. For the past 17 years timber has been treated onsite with both creosote and CCA. Recently there have been public complaints from the seaside residents of health problems – predominantly upper respiratory tract and skin-related – which they attribute to emissions from the plant.

A review of the results of medical surveillance conducted on employees at the plant indicates respiratory impairment in some, which may or may not be related, and which need to be confirmed and investigated further.

The plant proprietors have commissioned various reports in compliance with requirements from the Department of Environmental Affairs and Tourism. These include data from dispersion modeling of air pollutants in the vicinity of the plant, measurement of BTEX compounds in air on the plant and its perimeter, and measurement of CCA and creosote in onsite soil. The data indicate heavy but contained contamination of on-site soil and probably no contamination of groundwater. Dispersion modeling and sampling of air contaminants suggest that the latter are detectable beyond the site, but at levels well below international environmental health standards and odour thresholds for the chemicals investigated. The exception is benzene, which was measured at all sites, and estimated at fenceline concentrations, at levels higher than the international standard of $0.22 \mu g/m^3$ but well within the value of $5 \mu g/m^3$ referred to in one of the reports as the proposed standard for South Africa. The reports propose as solutions to the current situation:

- Relocation of the plant to an alternative site, pending approval from the relevant authorities

- Remediation of soil; of concern is that proposed remediation targets for the main pollutants appear to be relatively high in comparison with international standards

- Largely unspecified measures to control odours in the interim.

Environmental health concerns with respect to timber treatment operations have been recorded elsewhere. In the USA, such plants feature among the National Priorities or Superfund list of industrial sites in need of remediation. A review of public health assessments (PHA's) of such sites confirms that:

1. Wood treatment products may contaminate soil, water and sediment on and beyond wood treatment sites, and this contamination may persist in the long term. Off-site contamination may be aggravated by incidents such as spills, fires and flooding, as well as drainage of waste into off-site ditches or unlined reservoirs. These eventualities should be included in environmental impact assessments and risk management plans.

2. Contamination of soil, water and sediment may result in the exposure of human populations through inhalation, skin absorption and ingestion.

3. Complaints of health symptoms by residents in the vicinity of wood treatment plants have been documented elsewhere. These have included non-specific symptoms such as respiratory irritation and headaches, as well as increases in specific types of cancer.

Regrettably there have been few scientific studies of such health effects. Three studies, in the United States, have focused on the potential effects of dioxins and furans, which may be by-products of timber treatment products (particularly PCP and creosote), rather than the parent compounds. Although small, the studies suggest that contaminants may be carried offsite to surrounding residences as dust particles, that communities in the vicinity of treatment plants (particularly where PCP has been used) may be exposed to dioxins and furans, and that the exposure may be associated with a variety of health effects, from non-specific symptoms of respiratory irritation, to an increased risk of common conditions such as diabetes and hypertension, and more specific effects on neurological function, physician-diagnosed bronchitis and cancers.

At least one of the studies has been carried out in the context of a lawsuit by community members against the relevant treatment plant. While many of the PHA's mentioned above concluded that the associated health risks were 'indeterminate', the recommendations included restriction of access to sites in the long term, even after remediation efforts. Such a recommendation would obviously have a severe impact on potential future land use and land value.

It is clear that there is a need for wood treatment plant operators to be concerned about the potential effects of their operations on surrounding communities, for reasons of social responsibility and concern for public health as well as out of regard for the possible legal and economic consequences.

It is recommended that :

1. Epidemiological research into the potential exposure of communities in the vicinity of timber treatment plant in South Africa, and the potential health effects is very necessary, in order to clarify the extent of such exposure and its potential health effects and to provide information necessary for such exposure to be prevented in the future. Such research needs to take into account the possible health effects of by-products as well as parent compounds, and the potential for exposure through contaminated air, soil and water. It should also incorporate adequate environmental monitoring on- and off-site.
2. Where such plants are planned, they should be sited away from human habitation.
3. Control measures must be implemented on all plants to ensure that contamination of air, soil and water is prevented, in consultation with experts in industrial hygiene and environmental engineering. Effective engineering controls in conjunction with other measures – for example planting of trees to act as wind-breaks – may reduce dispersion of airborne contaminants to adjacent communities at existing plants.
4. Where contamination of soil and water has already taken place, remediation should be undertaken, towards targets that will permit the safe re-use of the affected land. There are currently no legislated remediation goals; SAWPA could perhaps begin to develop guidelines on such (practicable but sufficient) goals for its members.
5. Workers on wood treatment plants remain at highest risk of health effects. Measures that are effective in the protection of their health are critical during the operation of the plants as well as remediation efforts. Effective occupational health programmes, with adequate engineering controls, will reduce the potential for environmental contamination.
6. Ultimately, it is the toxicity of chemicals used in wood treatment that underly concerns regarding public health. It is imperative that the industry researches and begins to move towards the regular use of safer alternatives.

1. Introduction

Treatment of wood in South Africa, particularly for use in construction-related applications, currently entails the use of a range of potentially hazardous chemicals, some of which are no longer used in other parts of the world. Accordingly, the process of wood treatment is subject to government regulations concerning the use of hazardous chemicals in workplaces, and regulations to restrict the potential impact of such chemicals on the environment. The South African Wood Preservers Association (SAWPA) has undertaken to develop industry standards and guidelines to minimize the risk of exposure of treatment plant workers and environments to these chemicals.

A situation has arisen at a specific treatment plant in which members of a nearby community are objecting to its continued presence, alleging that they are suffering from health complaints as a result of exposure to chemicals used in the plant. The owner of the plant in question has approached SAWPA to conduct a literature review, using the situation at his own plant as a “case study”, to determine what evidence currently exists on potential health effects in communities in the vicinity of wood treatment plants, related particularly to the use of creosote and CCA.

2. Objectives

The objectives of the review overall are :

1. To review the current situation at the treatment plant in question
2. To review available health literature on potential health effects of creosote and CCA exposure in communities in the vicinity of treatment plants
3. To provide a summary of the literature and an indication of the state of knowledge concerning health risks to potentially exposed communities
4. Where possible, to make recommendations about the possible mitigation of such risks.

3. Methodology

The final report is based on :

1. A visit to the wood treatment plant in question and the surrounding areas and information provided by the proprietors and their employees
2. Review of documents provided by the proprietors – technical reports of investigations commissioned by them
3. Review of information provided by a community general practitioner who has treated community members and who has pronounced their complaints to be related to creosote exposure from the treatment plant .
4. Review of information provided by the occupational medicine practitioner responsible for the health surveillance of plant employees.
5. Review of the professional and academic health literature relevant to the potential health effects of wood treatment plant exposure on communities in the vicinity of wood treatment plants.

4. Findings

4.1 On-site assessment

creosote

cca

T

A

4.1.1 Background Information

C

B

Fig 1 : Layout of the treatment plant

The treatment plant (T) is shown in figure 1 above. It is situated in a coastal area, between a large national highway to the north (A), an up-market seaside holiday and residential area to the south (B), separated from the plant by a secondary road, and a lower-income community to the west (C). The CCA and creosote treatment areas are located towards the eastern and western ends of the site respectively, as shown, with intervening land used for stockyards of treated wood, bark stripping and sawing areas and, in the southeastern corner, currently unused buildings.

The current proprietors acquired the site in 1990 when it was a sawmill; at that time the entire area was zoned for industry. Treatment of timber with creosote and later CCA began in 1990/1991.

Subsequently, the proprietors were approached for comment when the municipality proposed that the land between the plant and the ocean be re-zoned for residential purposes; the proprietors submitted an objection to this proposal but the re-zoning went ahead.

Since then complaints have been received, from members of the holiday / residential community, of various health effects, including skin and respiratory complaints, eye complaints and others such as “liver problems” and “bleeding from the throat”. Another complaint is of “downpours’ of black dust/soot on washing hung out to dry. The plant proprietors and management are mystified by the latter, as they generate no dust or smoke that could be carried to the community. (Their boiler is wood-fueled and generally clean-burning – see below). No complaints have been received to date from residents of the adjacent, low-income community, nor a retirement community to the north-east of the plant, to which any airborne pollutants may be carried by the wind, which is predominantly south-westerly.

On the far side of the freeway on the northern side of the plant are other industries, not visible from the residential community, which the treatment plant proprietors believe may be contributing to any industrial pollution in the area. These include:

- A second wood treatment plant, operated by a large national timber enterprise
- A brickworks
- A sewage treatment plant.

The treatment plant employs approximately 80 workers on a full-time basis. There is a single shift, 7am to 5 pm, except for the stokers of the boiler; they work 2 shifts in order to keep the boiler lit between Sunday evening and Friday afternoon.

4.2.2 Processes and hazards

Inputs

Raw materials in the process are :

-wooden poles, predominantly pine (pinus radiatus and pinus pinaster), and some eucalyptus and saligna.

-creosote

-copper,chrome and arsenate.

Processes

Timber is transported to the plant from plantations in the province. It is offloaded, debarked and may be sawed to correct lengths or split, before being transported to the creosote and CCA plants for treatment. Treatment is carried out in closed cylinders, which are loaded with timber, filled with (heated) creosote or CCA from storage tanks, pressurized and then de-pressurizedand emptied, before the cylinders are opened and the treated timber removed. After treatment it is left to dry in stacks, then tied into bundles and stacked, in the stockyard at the southwest corner of the site, for collection.

There is a workshop onsite for vehicle maintenance, and treatment cylinders are emptied and cleaned annually by contractors.

The treatment areas are several hundred metres apart, as shown in Fig 1. The creosote treatment area consists of cylinders and storage tanks housed under corrugated iron roofing. Immediately adjacent, to the south, is a building housing the site managers' offices and eating and washing areas for staff, and to the west, the boiler. The CCA treatment plant is smaller, with a single cylinder and storage tank, and is less conspicuous from the road. There was extensive coating and pooling of creosote in and around the creosote plant area, and some pooling of CCA near the CCA treatment cylinder.

On the day of the site visit there was a noticeable smell of creosote in the vicinity of the creosote plant, stockyard and the western half of the plant. There was s mall amount of visible smoke from the boiler: the operator pointed out that this was because the wood was wet (there had been extensive rains) and said the boiler was usually clean burning. In addition there was an organic smell which was possibly related to composting of wet bark and sawdust. On the day of the visit, no odours were detectable from the residential area on the far side of the main road, but the wind at the time was onshore.

The most apparent potential sources of chemical emissions and odours from the plant are :

1. CCA from the CCA plant, maximal on opening of cylinders after treatment cycles and from evaporation of CCA off wet timber in the vicinity
2. Creosote from the creosote plant, also maximal on opening of the cylinder and from wet timber, but with greater potential for ongoing evaporation from pooled creosote and contaminated work surfaces.
3. Piles of wood dust and bark residue, as they begin to decompose, will contribute to odour and possible airborne contaminants in the vicinity of the plant; at the time of the visit this was marked, possibly aggravated by the wet conditions.
4. It is possible that soil contaminants may be dispersed to air, either through volatilization of polycyclic aromatic hydrocarbons and creosote components, or through dispersal of soil and dust particles onto which contaminants have become adsorbed. These scenario's are more likely during dry and windy weather and in circumstances in which contaminated soil is disturbed, such as clean up or remediation activities.

Outputs

7-9 loads of wood are creosote-treated and up to 5 loads of poles are treated in the CCA cylinder per day. Poles stand for a short period on the rails outside the cylinder before being hauled to a drying area close by, and later tied into bundles. Treated wood is stacked in the open before removal by buyers; creosoted poles are generally removed within 7 days of treatment, but CCA poles must lie for 14 days before they can be sold.

Waste management

Sawdust and removed bark is collected by a contractor and transported to his farm for composting, approximately 2-3 times per week.

Creosote and CCA waste are not actively removed, but drain into a sump beneath the cylinder, with some pooling around the treatment cylinders.

Comments and conclusions

The site visit took place at a time of heavy rainfall, which left the site muddy and may have aggravated odour component related to composting bark. However, it was noted that there was scope for improvements to housekeeping and maintenance which could have mitigated the odour problems somewhat. There were no engineering controls in place to reduce emissions, and recommendations were made, in a separate report, towards improvements in the interim, pending the relocation of the operations.

At the time of the visit, there was little visible smoke from the boiler; creosote odour was detectable on the western side of the plant but not from the residential area south of the plant. In drier conditions, and with a different wind direction, odours as well as contaminated soil particles and wood dust could possibly have been carried to nearby residences but this was not evident at the time of the visit.

4.2 Review of documents relevant to the site

The following documents were reviewed :

1. A report on the Atmospheric Impact of the Operations of (the plant in question),

2. BTEX Passive Sampling Prepared for environmental Consulting Services engaged by the site proprietors

3. A risk assessment report, January 2007

4. Draft: Environmental and Health Impact Report For The Undertaking Of Creosote Processes. *October 2007*

1. **Indicators of the potential for airborne exposure of residents in the vicinity of the treatment plant:** Reports 1 and 2 above, the "atmospheric impact" report and the BTEX sampling, dealt with the potential for exposure via airborne contaminants from the plant, emanating specifically from the creosote treatment plant.

   - The "atmospheric impact" report contained estimates of airborne concentrations of creosote constituent chemicals in the vicinity of the treatment plant. These estimates were based on (mathematical) dispersion modeling, integrating meteorological (wind speed and direction data) from 2 weather stations in the region with 2 sources of emission data; emission estimates from the USEPA and Australia, as well as observed experimental data produced by van Niekerk et al in a simulation of the wood treatment process, in which rates of emission from creosote baths were measured.

- The estimated annual and maximum hourly concentrations of benzene, ethyl benzene, xylenes, toluene, phenol, naphthalene, non-and carcinogenic polycyclic aromatic hydrocarbons were compared with international (USEPA) standards.

- For all annual concentrations the estimates were below the standards quoted, as were all maximum hourly concentrations except for that of benzene. The maximum hourly concentration of benzene at fence-line was 0.3µg/m^3 , higher than the USEPA annual standard of 0.22µg/m^3 , but according to the authors, less than the significantly higher proposed South African standard of 5µg/m^3.

- The report concluded that both long and short term exposure estimates indicated minimal or acceptable risk of resultant health effects in the surrounding community.

2. The BTEX passive sampling report contained the results of passive air sampling for benzene, toluene, ethyl benzene and xylene.

    - Passive samplers were placed at 6 sites on the treatment grounds; 1 at the creosote treatment vessel itself, and the others on the perimeter up- and downwind of the vessel.

    - Sampling was conducted over 2 periods, 1 over weekend and the other over weekdays, and the 12 samples thus obtained were analysed by gas chromatography.

- The results were compared with proposed 5µg/m^3

  environmental standard for benzene, and standards of 300, 2000 and 700µg/m^3 respectively for toluene, ethylbenzene and xylene.

  Results were all within these standards, although the benzene level at the treatment vessel approached 50% of the standard. (At all sites, the benzene level exceeded several-fold the ATSDR Minimum Risk Level standard of 0.22 µg/m^3, which was not referred to in this report).

- As shown in the table below, the data provided indicates that the levels of these chemicals experienced by residents is within environmental standards (except for benzene) and odour thresholds.

Table 1 : Reported levels of air contaminants at residential areas south of treatment plant

	Atmospheric Impact – dispersion modelling	**BTEX sampling**	**Reference value (max hourly)**	**Odour threshold**
Benzene	0.05->0.075µg/m^3	<1.04 µg/m^3	5 (??0.22) µg/m^3	4.8-15mg/m^3
Ethylbenzene	0.05->0. 075µg/m^3	<0.46 µg/m^3	1.6 µg/m^3	2mg/ m^3 Irritant>430mg/m^3
m-, o-, p-xylene	0.05->0. 075µg/m^3	<1.29 µg/m^3	7300 µg/m^3	4.35mg/ m^3
Toluene	>075µg/m^3	<1.88 µg/m^3	420 µg/m^3	9.4mg/ m^3 Discomfort>700mg/ m^3
Phenol	0.01-0.05 µg/m^3		1100 µg/m^3	0.021-20mg/m^3
Naphthalene	0.05->0. 075µg/m^3		3.3 µg/m^3	7-5340µg/m^3 (

3. **The risk assessment contained information relevant to soil and water contamination at the plant**.

- The plant was described as being underlain by sand transported from the dune ridge, underlying which was probably quartzite rock, probably more than 30m below ground level.

- The soil at both creosote and CCA treatment areas was found to be heavily contaminated, with maximum soil concentrations of 1771mg/kg (copper), 4243mg/kg (chrome) 10400mg/kg (arsenic) and 23773mg/kg (total polycyclic aromatic hydrocarbons representing creosote content).

- Although individual soil sample values, and sampling sites, were not quoted, the report concluded that CCA contamination was limited in area to 1000m^2, and in depth to less than 0.5 m.

- Creosote contaminated soil occupied an area of approximately 1 hectare but was confined to a soil depth of less than 1m.

- Major potential routes of human exposure from contaminated soil were felt to be ingestion of soil and plant material, dermal (skin) contact and inhalation of volatile compounds and particulate matter from the soil.

- Proposed remediation methods were removal of CCA contaminated soil to a landfill site, and bioremediation of the creosote contaminated soil. Given the proposed commercial/light industrial nature of future land use at the site, remediation targets consistent with typical worker scenario's, rather than reasonable maximum exposure, were proposed. Specific targets proposed were :

— Arsenic : 200 mg/kg

— Total PAH: 700mg/kg

— Benzo(a)pyrene: 20 mg/kg

- While a seasonal perched water table was likely to develop in the sandy layer, with maximum flow at the sand/rock interface, investigative wells detected no groundwater up to a depth of 30m, indicating that any static groundwater present is below this level.

- Soil tests indicated no significant vertical migration of contaminants at this level, and as there were no surface water collections on the site, the exposure for human exposure through contaminated water was not considered significant.

4. Draft Environmental and Health Impact report

This report is essentially a synthesis of the preceding reports, in which the following are highlighted:

- Soil in the vicinity of the CCA and creosote treatment areas has been contaminated with CCA and creosote but in a limited area and to depths of less than 0.5m and 30cm respectively.

- The result of dispersion modeling indicated that the annual average concentration for all constituents of creosote was within corresponding annual standards and that the risk of chronic health effects was minimal. It was suggested that, as the short-term concentrations of constituents including that of benzene were within proposed South African standards, the associated risk of short-term health effects was acceptable

- The dispersion modeling indicated that short-term concentrations of some creosote components may exceed odour thresholds. The nuisance value of this was reported to be difficult to estimate due to variations in individual susceptibility

- The report recommended the options of excavation and removal of CCA contaminated soil and bioremediation of creosote-contaminated soil.

- The chief intervention proposed to reduce atmospheric impacts (inhalational exposure) is relocation of the plant to Albertinia. In the interim, administrative measures are proposed to reduce the potential for evaporation of volatile organic chemicals by reducing the amount of treated ‘standing stock’ on the premises.

- The report also lists ‘point source treatments’ including enclosure of the treatment facilities, installation of capture hoods, extraction fans and chimneys and recommends that ‘some of these’ should be implemented ‘to show willingness’ to address issues raised by the community.

- The report recommends that staff at the facility be provided with protective equipment and health monitoring as long as it is in operation.

Comments and conclusions

Airborne contaminants

- If the data are correct, they suggest that residents are exposed to levels of airborne contaminants at levels that are well within environmental health standards, and below levels at which odours and irritant effects should be a problem. (It would be useful to see more tabulated data for the dispersion modeling indicating estimated concentrations at different distances from point source, in addition to the contour maps presented, to confirm this).

- An exception, and of concern, is benzene. Its concentration has been measured at different sites, and estimated in dispersion modeling, at levels above that considered safe by international authorities. That South Africa is apparently considering the introduction of a national standard several times higher should not detract from concerns about the potential long term effects, and there is a need to reduce levels of this and other environmental carcinogens to as low as possible.

- The monitoring and modeling were focused on the PAH's associated with creosote production. If CCA is still being used, as appeared to be the case at the time of the site visit, monitoring of the associated contaminants should be carried out.

- None of the reports provide for the occurrence of a major incident on site – major spill or fire – that might result in an increase in output of airborne emissions.

Soil and groundwater contaminants

- The reports indicate that there is fairly heavy contamination of soil in the vicinity of the treatment plants, but that it is limited in depth and extent. The exact measurement sites and results are not provided.

▪ Remediation is necessary if the land is to be useable in the future. However, the remediation targets appear to be higher than international norms, in the absence of locally legislated targets. As stated in the report they are :

- Arsenic : 200 mg/kg
- Total PAH: 700mg/kg
- Benzo(a)pyrene: 20 mg/kg

While they are consistent with some of the higher reference values, (intervention and health investigation levels), attached as appendices to the report, they are higher than others from the same table (soil quality guidelines/target values), as shown below.

Table 2 : International reference values supplied in the site risk assessment report

Authority	Guideline	Reference value (mg/kg)		
		Arsenic	PAH	Benzo(a)Pyrene
UK Dept for Environment, Food and Rural affairs + Environmental Agency	Intervention value – industrial/commercial land use	500	-	-
Australian National Environmental Protection Council	Health investigation value - industrial/commercial land use	500	100	5
Canadian Environmental Quality Guidelines	Environmental Soil Quality guidelines – industrial/commercial land use	12		0.7
Netherlands – Ministeroe van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer	Intervention value – all land use.	55	40	
	Target value	29	1	
France – Guideline values used for contaminated land management	Non-sensitive fixed impact value - industrial/commercial land use	120		25

They are significantly higher than remediation goals elsewhere. For example USEPA Preliminary Remediation Goals (for regions 4,6 and 9, for industrial and residential soil) are shown below.

Table 3 : USEPA soil remediation goals for arsenic and benzo-a-pyrene

	Residential soil	Industrial soil
Arsenic	0.39 mg/kg	1.6 mg/kg
Benzo(a)pyrene	0.015mg/kg	0.21mg/kg

- The process of remediation is likely to lead to increased exposures, particularly of workers, and care must be taken to minimise the generation of contaminated dust and ensure that adequate protection is provided.

- If the plant is to continue at the current site for any length of time, attention should be paid to the recommendations to ensure the protection of workers and mitigate odours and emissions.

- It was commented in several reports that the presence of Chromium in the contaminated soil was of lesser concern in its current form, trivalent chromium, than had it been present as hexavalent chromium. It should be noted that while this is essentially correct, recent studies indicate that trivalent chromium ingested in contaminated water, or presumably soil, may be converted in the process of absorption to the hexavalent form, and so where there is any potential for its ingestion its potential toxicity should not be underrated.

4.3 Review of information from community general practitioner

A community general practitioner has been quoted in the media on health problems in the residential community that he attributes to emissions from the treatment plant. He was contacted and asked to provide information on the extent and nature of relevant health complaints among his patients.

He did not supply any documentation, but reported telephonically that the major complaints are 'sinus' symptoms and skin rash associated with the creosote smell, and one of his patients is an asthmatic who has had severe bronchospasm associated with the creosote smell. He feels there is a need to do a formal community survey; he sees 3-5+ such cases, but there are probably another 10 GP's seeing people from the same area.

In addition to the above complaints from the higher income residential area, he has 1 or 2 complaints from residents of the lower income community west of the plant ; these are complaints of "sinus".

He said that generally, the reported symptoms occur in relation to active production at the plant and wind direction.

4.4 Review of information from medical surveillance of treatment plant workers

The occupational medicine practitioner carrying out medical surveillance of the plant's workers was requested to provide information relating to complaints or findings from the surveillance programme. This was done to determine whether workers were experiencing health effects similar to those reported from the community.

A spreadsheet was received containing summaries of findings from medical examinations carried out on 46 workers between September and November 2007. Included were comments on audiometry and lung function testing as well as general comments, but biological monitoring was not conducted.

Under ' medical', there were

- 24 recorded as 'normal'

- 1 case of 'skin infection' and 1 of 'dry skin'
- 3 cases of suspected or confirmed TB
- 4 cases of hypertension
- 2 cases of diabetes
- 2 cases of poor vision
- 2 cases of lower back pain
- 2 cases of hearing loss
- 1 case of asthma
- 1 case of ?Bell's palsy

Among the audiometry results, 7 had a percentage hearing loss in excess of 10%, compensable if consistent with noise induced hearing loss.

Of the lung function tests:

- 27 indicated 'normal' lung function
- 15 indicated 'restriction' – mild, moderate or severe
- 3 indicated 'obstruction' – mild or severe
- 1 showed mixed obstruction/restriction.

Comments

The 15 cases of restrictive lung function impairment need to be further investigated.(This would involve validating the results and interpretation of the tests, determining what risk factors for such impairment were present in the histories of those affected, determining what common workplace or other exposures were experienced by those affected, and comparing the distribution of such factors between those with restrictive impairment and those with normal lung function). The finding may be related to technical difficulties with testing, or to unrelated conditions such as fibrosis associated with TB (although this would reflect a very high TB prevalence), but is not indicative of the kind of impairment associated with smoking.

4.5 Review of available literature on health effects of wood treatment plant emissions on surrounding communities

It has not been possible to find any review articles on the potential or manifested health effects on communities of wood treatment plants in the vicinity, nor any large epidemiological studies. Published review articles would have provided an expert analysis of the value and findings of research done in the field, and large epidemiological studies would have provided greater statistical power to studies, and greater certainty regarding the validity of the results presented.

In the USA, relevant but small studies have been conducted at 3 sites in the United States, as well as several "Public Health Assessments' of existing or previous treatment sites by the US Environmental Protection Agency. The findings of these are summarized below.

1. Wood treatment products may contaminate soil, water and sediment on and beyond wood treatment sites, and this contamination may persist in the long term.
2. Contamination of soil, water and sediment may result in the exposure of human populations
3. Complaints of health symptoms by residents in the vicinity of wood treatment plants have been documented
4. Studies of communities in the vicinities of 3 separate wood treatment plants in the US report evidence of health effects, contamination of indoor dust with dioxins and furans, and elevated levels of dioxins in the blood of residents. The presence of dioxins is related primarily to the use of PCP as a wood treatment product, but furans are encountered in creosote wood treatment as components or by-products of creosote.

These points are discussed in further detail below.

1. **Wood treatment products may contaminate soil, water and sediment on and beyond wood treatment sites, and this contamination may persist in the long term.**

Wood treatment sites have operated in the United States and other parts of the world for nearly a century. In the US, a large number appear on the Environmental Protection Agency's National Priority/Superfund list of sites of environmental concern which have undergone, or are to undergo, environmental remediation to rectify contamination persisting from industrial processes and waste. These sites have been subjected to formal Public Health Assessments (PHA's) by or on behalf of the EPA, which are matters of public record.

14 such PHA's were reviewed for the purposes of this report, in states including Texas, Idaho, Alabama and Oregon. They indicate that:

- Wood treatment processes may result in the long-term contamination of :
    - Surface and sub-surface soil
    - Surface water and sediment
    - Groundwater, by vertical migration of contaminants through soil
    - Marine life

  In many cases the PHA's were conducted only after wood treatment operations ceased, and contamination of these media was measurable years later.

- Air pollution was not often measured, and only when plants were operational or an identifiable source of pollution persisted. Airborne contaminants may take the form of volatile organic chemicals, smoke, dusts, and possibly chemicals or their by-products adsorbed onto dust (wood dust or soil) particles.

- Contaminants may be transported off-site in these media. This seems to be described particularly where chemicals have been stored in unlined facilities, waste has been disposed of into surface ditches or water channels, and where there have been major incidents such as spills, fires or flooding.

- In at least 1 case, soil remediation did not completely reduce contaminant levels in surface and subsurface soil, and concerns over soil washing from a clay-capped vault of sequestered contaminated soil necessitated a further assessment.

2. **Contamination of soil, water and sediment may result in the exposure of human populations**

Exposure occurs when a completed *exposure pathway* exists : this is the term used to refer to the route a contaminant takes from its source to a person. It consists of five elements, all of which must be present at the same time, or can reasonably be expected to be present at some time. These are:

1. *A source of contamination*

    here, the wood treatment chemicals

2. *Environmental media and transport mechanisms*

    media being air, soil, water, marine life

3. *A point of exposure*

    eg handling of contaminated soil onsite by workers, inhalation of contaminated air by people on-or off-site

4. *A route of exposure*,

    inhalation, ingestion or absorption through skin

5. *A receptor population.*

It was concluded in most of the PHA's that, in addition to the plant workers who had obviously been exposed during plant operations and remediation, complete or potential exposure pathways existed for trespassers on site, nearby residents, people using forests and streams around the sites for recreation etc. In 2 cases, residential and or commercial development had already taken place on site, and ongoing contamination necessitated extensive remediation and/or relocation of families. Of particular concern is the potential exposure of children: both because of their small size and the immaturity of their metabolic systems, lower levels of exposure may be toxic to them; because of their height they may be exposed to higher levels of contaminants closer to the ground, and because of their habits – eating soil (pica), playing in the dirt – they are likely to be exposed to contaminated soil and surface water where adults may not.

For this reason, even though there was often not sufficient data to declare sites public health hazards (and they were therefore declared to be indeterminate health hazards), the PHA recommendations for most sites was that, as well as further sampling and remediation, access should be restricted indefinitely by means of fencing and labelling. This would have clear implications for the further use and value of the land on which the sites were located.

3. **Complaints of health symptoms by residents in the vicinity of wood treatment plants have been documented elsewhere.**

The PHA's documented community health concerns expressed at community meetings, letters to newspapers etc. As well as concerns about the safety of drinking water and risk of cancers, these included complaints of :

- menstrual changes, skin complaints, lymphadenopathy, flu-like symptoms, colds and headaches
- respiratory difficulty, liver disease, renal cancers
- past and present chemical odours, cancer concerns, 'spots on lungs', bronchitis

- odours, eye and throat irritation, headaches and nausea. .. and reports of excess cancer rates among current and future teachers at a nearby school.

None of the PHA's included comprehensive health surveys. In 2 in which concerns over cancers had been expressed as community concerns, local cancer registries were reviewed. In one of these, an excess of sarcomas in the community above the numbers expected for the population was observed, and further investigation was recommended. At another, an excess of cancers of the lung, bronchus and breast was ascribed to familial risk and family history.

4. **Studies of communities in the vicinities of 3 separate wood treatment plants in the US report evidence of health effects, contamination of indoor dust with dioxins and furans, and elevated levels of dioxins in the blood of residents.**

a. *Mississippi*

The first study, published by Dahlgren et all, in 2003, examined health effects among residents in the vicinity of a still-operating Mississippi wood treatment plant that utilized creosote since 1929, and PCP between 1959 and 1974. Residents complained of creosote odours and associated symptoms including headache, nausea, eye irritation and sore throat.

The study was based on case control methodology. Cases and controls were subjected to a battery of tests and a questionnaire. The cases were 214 residents, out of a total of 1269 in the vicinity of the treatment plant, and 139 controls were chosen from 479 residents of a similar neighbourhood in Alabama without a source of chemical exposure. Controls were matched by gender and age; all cases and controls were African American.

Symptoms of respiratory and skin irritation were scored higher for severity among cases. Scores were significantly higher among adult and child cases than controls for symptoms of irritation of eyes, skin and upper respiratory tract (mouth, nose and throat) at a 95% level of significance. Cases of physician diagnosed chronic bronchitis were significantly more common among cases than controls, as were symptoms consistent with chronic bronchitis. While the frequency of physician diagnosed asthma was not significantly different between cases and controls (13.1 vs 12%), symptoms suggestive of asthma were significantly more frequent among cases.

Symptoms described as neurological were scored significantly higher among cases than controls. Among adults these were irritability, light-headedness and extreme fatigue, with differences in score of 2.8 to 2.9 at a 95% significance level. Among children these were irritability, lack of concentration, extreme fatigue, headache, long term memory loss, recent memory loss and instability of mood (range of difference 3.1 to 5.2, at a 95% significance level).

Differences were also noted between cases and controls on neurophysiologic testing.

Differences in haematological parameters (blood cells and haemoglobin) were also noted. Lastly, there was a significantly higher rate of cancer among the population of 1269 residents from whom the cases had been selected than the referent population of 479 from whom the 139 controls were selected – 10% vs 2.08%, statistically significant at a 95% level.

Although the researchers presented no results of environmental monitoring of the levels of contaminants in the vicinity of either cases or controls, they reported that testing by various parties had indicated contamination of soil and sediment in the vicinity of residents' homes with creosote constituents, as well as dioxins and furans. Contamination was facilitated by the discharge of waste to drainage ditches which flowed through the area into a river and which flooded during rainy seasons, and in one incident a fire at the plant had burned for more than 8 hours, polluting the area with smoke and soot.

Cases in the study were involved in a legal suit against the plant for the health effects. The researchers, noting the suggestion by observers that this may have biased their study, referred to research on selection bias that indicated that plaintiffs were not more likely to enhance their symptoms than a normal population. An 'unlikely symptom' question in the questionnaire was used to assess malingering, and the process described for the selection of cases and controls appears to be adequate to prevent the selection of a biased sample. Although measurements of contaminants in the environment or body fluids of cases or controls are not available to provide an assessment of any dose-response relationship, case-control methodology is considered to provide relatively strong evidence of an association. This study suggests that residents in the vicinity of a treatment plant may experience irritation of the skin and mucous membranes, effects on their respiratory and neurological function, and an increased risk of cancer. The outcome of the legal claim to which the cases were a party is unknown.

The same researcher subsequently reported, in other papers, the last in 2007, results of environmental monitoring and biological monitoring of dioxin levels carried out in the vicinity of the treatment plant, and among a small group of residents. Mean levels of several dioxin and furans in household attic dust were reportedly higher for most congeners than the state legislated soil cleanup target levels which were used as a reference, there being no legal reference for such levels in indoor dust.

Samples of blood were taken from 29 residents, and were found to contain mean levels of 2 specific dioxins, OCDD (octachlorodibenzo-p-dioxin) and HpCDD (hexachlorodibenxo-pdioxin) 2-3 times higher than the levels found in a sample of pooled blood from a reference population. These levels were considered consistent with exposure to PCP, but it was not possible to assess whether this exposure was historical or ongoing, given the persistence of these compounds in environmental media and in biological tissue.

The findings reported in the 2007 paper were challenged by experts employed by the opposing legal team, raising various issues related to the methodology and interpretation of findings. These included the comparison of blood results with a single pooled sample rather than multiple samples which would have allowed greater statistical analysis, the fact that while the identified dioxin congeners were elevated the total dioxins were not, and the fact that the reported classification of the site by the US Environmental Protection Agency had subsequently been revised to indicate that groundwater contamination was considered satisfactorily controlled. They also questioned the significance of contamination of attic dust, as residents were unlikely to be exposed to such dust on a frequent basis. The response by the original authors pointed out that their chief findings stood, and refuted some of the ground on which their article had been challenged. Blood levels of dioxin congeners consistent with PCP exposure were elevated, and levels of attic dust indicated contamination of indoor dust and allowed its quantification. They had been unaware of the revised EPA classification of the site, and intended to challenge it based on their findings.

DIOXINS AND FURANS

The chlorinated dibenzo-p-dioxins and dibenzo-furans are loosely referred to as dioxins/furans. Of the 75 dioxin/furan compounds, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) is the most toxic. They are present as trace impurities in some synthetic chlorinated chemicals. They neither occur naturally nor are intentionally manufactured except as a reference standard, but can be inadvertently produced in very small amounts as an impurity in some chemicals and as a waste incineration product. Dioxins may occur in the use of PCP, and furans are mentioned among the many constituents of creosote. Some researchers report that their production may be increased during the process of heating and pressurizing during wood treatment. They have not until relatively recently been considered in studies on the health effects of wood treatment products, but are a topical and emerging issue in many industrial settings.

Chlorinated dibenzo-*p*-dioxins (CDDs) comprise a family of 75 different compounds commonly referred to as chlorinated dioxins, divided into eight groups of chemicals based on the number of chlorine atoms (1-8) in the compound. CDDs exist in the environment as mixtures containing a variety of individual components and impurities. They tend to be associated with ash, soil, or any surface with a high organic content, such as plant leaves. In air and water, a portion of CDDs may be found in the vapor or dissolved state, depending on the amount of particulate matter, temperature, and other environmental factors. 2,3,7,8-TCDD is odorless.

Chlorinated dibenzofurans are a family of 135 compounds, containing 1-8 chlorine atoms attached to the parent chemical, dibenzofuran. Few have been produced in large enough quantities to permit the study of their physical and chemical properties. They are often found in association with CDD's, with similar toxic effects.

Dioxins and furans are of concern because of evidence of health effects, including cancer, as well as their persistence in blood, (with half lives estimated at between 7 and almost 20 years, and in the environment). **Other possible health effects include immunotoxiciy, reproductive health effects (demonstrated to date in animals), chloracne (a pustular skin rash) and effects on the liver in humans. One of the dioxins, 2,3,7,8 TCDD is classified by the IARC as a (Group 1) human carcinogen**; the other dioxins and furans are classified as Group 3 – not classifiable as to their carcinogenicity in humans, i.e. evidence for their human carcinogenicity was considered inadequate at the time of the classification in 1997.

Mixtures of dioxins are evaluated by assessing their potential toxicity relative to that of TCDD, and this is measured as dioxin TEQ (toxic equivalent) concentration.

b. *Alabama*

A second study, published by Hensley et al in 2007, was conducted in the vicinity of an Alabama wood treatment plant that had been in operation from the mid 1960's to the 1990's, utilizing CCA, creosote and PCP. The study consisted of 2 parts : blood measurements and attic dust measurements. The results indicated elevated levels of dioxin in residents' blood, and of dioxins and other contaminants in attic dust.

Blood measurements : Researchers measured blood dioxin levels in 21 residents who had illnesses that 'could potentially have resulted from exposures to contaminants released by the facility', all of whom had been exposed to contaminants during its operation for at least 18 years, 4 as employees. The 95th percentile of the population distribution of blood dioxin TEQ's was 39pg/g lipid; the 50th percentile for the 21 residents was 35.5pg/g, the 75th 53.6, the 90th 65 and the 95th 70pg/g. In other words, 50% of the residents had a dioxin TEQ higher than that of the top 10% exposed in the national survey.

Attic dust measurements: Attic dust, according to the authors, is a useful means of evaluating past exposure; dust from the external environment infiltrates the attic over years, settles and is preserved from weathering. Samples of dust were taken from the attics of 11 homes within 1.5km of the perimeter of the treatment plant site. Dust samples contained levels of dioxin (total dioxin TEQ ng/kg), arsenic and total PAH TEQ (mg/kg) that were higher than the USEPA PRG (Preliminary Remediation Goal) values for soil applicable to the treatment site. The USEPA PRG values were also exceeded for chromium at 2 houses and for copper at another. Dioxin TEQ levels ranged from 8.4 to 501.5ng/g, with an average of 145.5, where reference levels were 3.9. Total PAH TEQ ranged from 0.01 to 7.62 mg/kg, with an average of 0.98, reference level (for benza(a)pyrene)) 0.062mg/kg.

Table 5 : Attic dust results compared with Soil Remediation Goals

Compound	**Range of measurements**	**USEPA Region 4 PRG**
Dioxin (ng/kg)	8.4-501.5	3.9
Arsenic (mg/kg)	3.1-261.8	0.39
Chromium (mg/kg)	11.9-39.6	30
Copper (mg/kg)	8.6-122	3100
B(a)P (mg/kg)	0.01-7.62 (PAH TEQ)	0.062

While no formal health assessments were carried out, 13 separate health conditions possibly related to arsenic, dioxin or PAH exposure had been reported, the commonest of which were hypertension, diabetes, breast cancer and lung cancer. No information was provided on other personal factors that may have contributed to these conditions.

c. *Florida*

A third study, published by Karouna-Renier et al in 2007, assessed levels of dioxins and furans, and associated health effects, in the blood of residents in the vicinity of a wood treatment plant in Florida that had operated between 1942 and 1982, utilizing PCP and creosote.

Blood samples were taken from 47 residents, 9 of whom had been employees of the treatment plant. The median TEQ for these samples was 21.5pg/g blood lipid, higher than that reported by the CDC for US adults over 20 in 2005 (13.6pg/g lipid) as well as other comparison populations presented. Levels were particularly high for OCDD and 1,2,3,4,6,7,8-HpCDD. The study reported a small association between hypertension and TEQ in the sample (Odds ratio 1.108, 95%confidence interval 1.108-1.204), but not between cancer or diabetes and TEQ.

d. Conclusion

- The 3 studies reported above are small and are not without their flaws. Their interpretation is made more difficult by questions for which there appear currently to be no answers –eg, what standard should be used to assess contamination of indoor dust?

- They indicate a shift of focus among researchers from the health effects of wood treatment products themselves to the effects of exposure to dioxins and furans that may be a by-product of wood treatment, particularly with PCP.

- They also indicate that contaminants in dust particles may be transported off-site and may persist in residences in the vicinity of wood treatment plants.

- Some of the health effects described –hypertension, diabetes -are mult-factorial and difficult to ascribe to a single environmental exposure. Symptoms such as poor concentration and light-headedness are also rather vague.

- However, the statistically significant increased prevalence of physician-diagnosed bronchitis, asthma symptoms and cancer, and the statistically significant differences in neurological test batteries, in conjunction with the elevated blood and environmental levels add weight to the association with health effects.

5. Conclusion and recommendations

There is currently not sufficient knowledge about the public health effects of wood treatment plants either to refute the claims of health effects expressed by the community around the plant of concern, or to identify clearly-defined health outcomes and associated parameters (distance from plant, nature and level of contaminants in emissions, particular susceptibilities) which promote their occurrence.

There is evidence that environmental contamination may occur, and may result in human exposure, not only to the treatment products themselves but also to by products. There is some evidence of public health effects in relation to exposure to dioxins and furans, which are an emerging issue for discussion and research in occupational and environmental health. Although based on small numbers and only a few reports, there may be an associated cancer risk that requires investigation. Lastly, the examples from the US indicate that there are precedents not only for the type of controversy surrounding the plant under discussion, but also legal claims. Also, there is evidence that the long term contamination of land used for wood treatment has limited the subsequent use, and presumably value, of the land concerned.

It is clear that there is a need for wood treatment plant operators to be concerned about the potential effects of their operations on surrounding communities, for reasons of social responsibility and concern for public health as well as out of regard for the possible legal and economic consequences.

It is recommended that :

1. Research into the potential exposure of communities in the vicinity of timber treatment plant in South Africa, and the potential health effects is very necessary in order to clarify the extent of such exposure and its potential health effects, and to

provide information necessary for such exposure to be prevented in the future. Such research needs to take into account the possible health effects of by-products as well as parent compounds, and the potential for exposure through contaminated air, soil and water. It should also incorporate adequate environmental monitoring on- and off-site.

2. Where such plants are planned, they should be sited away from human habitation.
3. Control measures must be implemented on all plants to ensure that contamination of air, soil and water is prevented, in consultation with experts in industrial hygiene and environmental engineering. Engineering controls in conjunction with other measures – for example planting of trees to act as wind-breaks – may reduce dispersion of airborne contaminants to adjacent communities at existing plants. Such measures are most easily introduced at planning stage, and relevant professionals should be consulted during the planning of any plants. Included in the structure of treatment plants must be measures to reduce emissions from the cylinders during and immediately after treatment, as well as from freshly treated wood.
4. Where contamination of soil and water has already taken place, remediation should be undertaken, incorporating targets that will permit the safe re-use of the affected land. There appear to be no legislated remediation goals for South Africa; SAWPA should perhaps begin to develop guidelines on such goals for its members.
5. Workers on wood treatment plants remain at highest risk of health effects. Measures that are effective in the protection of their health are critical during the operation of the plants as well as remediation efforts. Effective occupational health programmes, with adequate engineering controls, will reduce the potential for environmental contamination.
6. Ultimately, it is the toxicity of chemicals used in wood treatment that underly concerns regarding public health. It is imperative that the industry researches and begins to move towards the regular use of safer alternative.

6. Appendix A : Public Health Assessments of 14 US timber treatment plants, summarized

Reference values

Among the international comparison/reference values that may be used to evaluate contaminant concentrations in different media (soil, sediment, water and air) are the following, which are referred to in the public health assessments reviewed:

- Cancer Risk Evaluation Guides (CREGs), are estimate of contaminant concentrations that would result in one excess cancer in a million persons exposed over a lifetime (70 years).
- Maximum Contaminant Levels (MCLs) represent contaminant concentrations that the US EPA deems protective of public health over a lifetime, at an exposure rate of 2 liters of water per day.
- Proposed Maximum Contaminant Levels (PMCLs) are MCLs that are being proposed by EPA. MCLs and PMCLs consider factors such as the technology available to achieve that concentration as well as health issues.
- Minimal Risk Levels (MRLs), developed by the ATSDR, are health-based guidelines used to evaluate noncarcinogenic adverse health effects for routes of exposure such as ingestion and inhalation, and for exposure durations including acute (less than 14 days), intermediate (15 days to 364 days), and chronic (greater than 365 days).
- Reference doses (RfDs) and reference concentrations (RfCs) have been developed by the USEPA where no MRL's are available for ingestion and inhalation exposure, respectively

Public health assessments

1. **Brunswick Wood preserving**

- Operational 1958-1991, utilizing creosote, PCP and CCA
- Post-closure remediation – removal, dealing with surface water run-off, draining of holding tanks, dissembly of CCA equipment. Remediation interrupted by shortage of funds; 127000tons of soil stored onsite in lined and covered cells.

- Sampling in 1991/92 indicated raised levels of compounds (PCO, PAH's, As, Cr, dioxin) in soils up to 9 inches below surface + contamination of groundwater by vertical migration of contaminants to underlying aquifer.
- Sampling of municipal wells in 95/96 showed no contamination; sampling of private wells within 1 mile of site in 1991/92 showed contamination in1.
- It was concluded that potential groundwater contamination was difficult to assess, but that there was considered to be no apparent risk to municipal wells, the risk of exposure through water from private wells and contaminated fish was indeterminate.

2. **Hoosier wood treatment, Indiana**

- Operational 1975-94, utilizing creosote, PCP, CCA
- Site abandoned post 1994, developed in 2000 for business and residential purposes
- Sampling 2000:

  Arsenic: up to 59ppm in surface soil, 12 ppm in sub-surface soil

  PCP : up to 38 ppm in surface soil, 0 below surface

  No contamination of sediment or drinking water but groundwater inadequately characterized

- Soil levels of As and PCP were higher than calculated ATSDR comparison value for a child, and much higher than that for a pica child. The levels were not considered a public health hazards in the context of a worst case estimated dose calculation for As in a pica child – assuming exposure 7 months per year, 7 days per week, 6 hours per day for 3 years.
- However annual monitoring of private wells was considered necessary.

3. **Southern Wood Piedmont Company, Georgia**

- Operational 1915-1986, creosote and PCP
- In early years wastewater was discharged into an unlined settling tank, then discharged into city sewers.
- Remediation post 1986 entailed removal of structures, excavation of contaminated soil, erection of a perimeter fence, excavation of contaminated sediment from drainage dykes.
- 1984-1987 samples :

  On-site surface water contamination with naphthalene at 206 ppb (ref 20), PCP 1512ppb (ref 10)ppb, offsite water PCP6.8ppb

  Dioxins in sediment onsite at total TEQ of 0.00588, off-site 0.0000018-0,00000074

▪ However, the conclusion was that despite the onsite water and sediment contamination that the (abandoned) site was not a health hazard as exposure was neither occurring nor expected. 1 area of contamination off-site was not deemed a public health hazards as it was unsuitable for recreational use.

▪ Exposure through ingestion of contaminated fish was an indeterminate health hazard.

▪ The continued restriction of access to the site, and sampling of fish, were recommended.

4. **American Crossarm and Conduit**

- Operated 1930's – 1993, including PCP
- Flooding in 1986→release of 10000 gallons PCP, contamination of on-and off-site soil and surface water
- Community health concerns included menstrual changes, skin complaints, lymphadenopathy, flu-like symptoms, colds and headaches
- 1988/9, EPA incinerated on-site soil, sludge, debris, stored 200+ tons of ash on-site. 1990 declared site a public health hazard and 1991 added surface gravel to reduce risk of airborne contaminated dusts. 1993 implemented extensive remediation plan – included excavation of soil from surrounding commercial and residential properties, excavation and demolition on site, fencing and restricted access.
- 1993 sampling:
    - On-site surface soil

        i. PCP up to 130ppm (ref 6 – CREG)

        ii. Carcinogenic PAH's up to 258ppm (ref 0.1 – CREG)

        iii. Dioxin up to 0.143 (ref 0.000005 (EMEG)

    - On-site subsurface soil:

        i. PCP up to 250 ppm

        ii. Carcinogenic PAH's up to 54.5

        iii. Dioxins ND

    - Groundwater contamination : PCP in dissolved phase and floating phase mixed with diesel, PAH contamination
    - Off-site surface soil:

        i. PCP up to 13ppm

        ii. Carcinogenic PAH's up to 32.9

        iii. Dioxins up to 0.00136

    - Offsite surface water: PCP, PAH's and dioxins present but below reference levels
    - Offsite sediments: Dioxins 0.000593, PAH's 36.65, PCP in half samples up to 0.19ppm. In wetland sediments, PCP below reference levels, PAH's and dioxins above reference levels.
- Conclusions:
    - Exposure pathways : future floodwaters, residential soil and dust. Drinking water a potential exposure pathway (groundwater not currently used for drinking)
    - Dose estimations indicated increased cancer risk from PCP in onsite soil, low increased risk from BaP for 20 years of work exposure. Minimum Risk Level for dioxin was exceeded for a child playing in off-site soil, a child trespassing on-site for 1 day per week and for an adult worker present 5 days per week.
- Site declared a public health hazard

5. **Atlantic Wood Industries**
    - Waterfront of Portsmouth, Virginia
    - Active wood treatment 1926-1991,(Creosote + PCP, ?CCA; CCA-treated wood stored) wood storage and distribution since.
    - Arsenic, PCP, benzene and PAH's detected in surface soil, groundwater, sediments onsite and in the adjacent river.
    - Remediation to date of assessment included excavation of soil.
    - 1966-1982: waste stored in unlined waste lagoon, backfilled 1983
    - Community health concerns : opposition to incineration as clean up method, water quality concerns (rivers and bay)
    - Monitoring – onsite

        1. Air: naphthalene along boundaries at 6 -62ppb (<8μg/m^3 state pollution level)

        2. Soil and groundwater

            - Benzapyrene (soil CREG 0.1ppm, water 0.005ppb)

                i. Surface soil 840, subsurface soil 5200ppm

                ii. Groundwater 130ppb

            - Benzene (water CREG 1ppb)

                i. Groundwater 58ppb

            - PCP (soil CREG 6ppm, water 0.3ppb)

                i. Surface soil 970, subsurface 290ppm

                ii. Groundwater 1300ppb

- Arsenic (soil CREG 0.4ppm, water 0.02ppb)

  i. Surface soil 495, subsurface soil 445 ppm

  ii. Groundwater 876ppb

- Onsite sediment and surface water also contaminated
- River sediment samples showed contamination, predominantly with PAH's, as did oysters sampled from the river.

6. **Federal Creosote**

- 53ha site – commercial and residential – built over a former wood treatment facility where creosote was main treatment between 1910 and 1956, current development began in mid-60's after 2 lagoons and canals containing used creosote were covered with fill and the site was graded.

- 1996 monitoring confirmed contamination of a residential sump pump, PAH's in sub- and surface soils. (Followed appearance of black tarry substance in sump pomp and in a sinkhole that developed at a sewer inlet)

- Sampling in 1997 &8 indicated unacceptable risk at 19 houses

- Resulted in remediation with groundcover in 17 homes, permanent relocation of 16 families.

- Groundwater sampled showed contamination but plume had not spread to the municipal supply; ongoing monitoring was necessary.

- ATSDR opinion in 1998 was that there could be toxicity of home grown vegetables, and that sampling was necessary.

- Indoor air sampling showed low level PAH contaminants in some homes, most traced to household cleaners and chemicals used.

- Based on surface soil samples, average cancer risks were calculated:

  - Adults 1.8 cases/10 000 exposed

  - Children nearly 7 cases/10 000 cases exposed.

- Conclusion: post remediation surface soil not a health hazard, sub-surface soil not a hazard unless disturbed.

7. **Hart creosoting company, Texas**

- Creosote wood treatment 1958-1993

- 1984-99, cited for violations of environmental legislation, groundwater contamination
- 1999, placed on National Priorities List
- 1995 remediation by EPA

    i. Water from onsite surface impoundments treated, discharged

    ii. Contaminated sediments, soils and hazardous materials excavated from visibly contaminated areas onsite and enclosed in a clay-lined and – capped storage pit, surrounded by an intruder-resistant fence, warning signs posted

- Max residual levels off-site: (low-level, would require ingestion in unlikely quantities to have health effect)

    i. Sediment BaP1.28mg/kg

    ii. Groundwater contamination 9-12 inches below surface, with no indication of contamination of wells/water sources

    iii. PAH's in surface water of nearby creek, but would need to ingest 2l/day for harmful effect – unlikely (?).

8. **Jasper Creosoting, Texas**
    - 1946-96: creosote, PCP
    - Surrounding residential neighbourhood on 2 sides
    - Contamination of offsite soil, sediment, water via wastewater discharge to an offsite drainage ditch: PAH's, PCP and dioxins
    - Onsite soil contamination with PCP, dioxins, BaP
    - Soil previously contained in clay cap washing out from the area and reassessment was necessary.
    - Community concerns : respiratory difficulty, liver disease, renal cancers (response to latter: unlikely)
    - Indeterminate PHH: limited data

9. **Koppers, Delaware**

    - NPL site – onsite contamination with PAH's, As etc

    - 1929-71 creosote, PCP. Post 1971 sold,→ manufacturing plant→sewage treatment plant; operated til 1977, then area fenced, locked

    - Site visit 1990: visible contamination of building foundations etc. 19500 inhabitants within 3 mile radius, nearest ¼ mile away

- Previous complaints that odours cased nausea, burning of throats and noses, watering of eyes.
- 1984 – on- and offsite contamination of sediment and soil
- No groundwater data, but likely that shallow aquifer contaminated by proximity of contaminated subsoil.
- Soil levels indicated increased health risk for pica (soil-eating) children for PAH's in on-site sediment and soil, and As in off-site sediment
- Indeterminate health hazard- insufficient data
- Recommendations:
    - Restrict site access
    - Further sampling
    - Potential exposure pathways :
        i. Ingestion, dermal exposure – surface soil, sediments
        ii. Ingestion, dermal, inhalation exposure –private well water
        iii. Inhalation – contaminant vapours
        iv. Ingestion – terrestrial, aquatic organisms

10. **McCormick and Baxter Creosote Company, Oregon**
    - 1944-1991: Creosote, PCP, CCA and Zn. Owners vacated 1991 for remediation.
    - Population: 100 within ½ mile, 8000 within 1 mile.
    - Periods of direct discharge into adjoining river, 2 major spills. Contaminated soils removed more than once.
    - Public health hazard:
        i. Employees – As, creosote, PCP, PCD and DBF – by ingestion, inhalation, skin exposure
        ii. Exposures on the shoreline and onsite –by skin exposure
        iii. Dioxin exposures from consumption of contaminated crayfish
    - Indeterminate health hazard – inhalation (no sampling data) and reports of skin burns from wading in river
    - Community health concerns: past and present chemical odours, cancer concerns, 'spots on lungs', bronchitis

- Sampling indicated on-and offsite contamination of soils, sediment and water, with As and PAH's, and of offsite marine animals with PAH's and zinc.
- Among the exposure pathways considered to be present were air, on-and offsite, through there was no sampling data to support the latter

11. **Palmeto Wood Preserving, South Carolina**

- 1963-1985: fluoride, CCA, PCP.

- 1982: raised levels of chromium found in residential wells

  →installation of municipal water line

  Soil clean-up and containment

  Groundwater cleanup

- Sampling indicated onsite soil (As, Cr and BaP) and groundwater (As and Cr) contamination; levels of organic vapours in air were below action levels.

  There was evidence of off-site soil, sediment and groundwater contamination with As and Cr.

- Classified as an indeterminate health hazard, with completed exposure pathway through offsite groundwater to dermal absorption and ingestion. Residents – adults and children – as well as workers could also potentially be exposed via soil/surface water/sediment and possible air

- Recommendations were for further sampling and groundwater remediation.

12. **Poles Inc Wood treatment facility, Idaho**

- Pole peeling and storage facility where wood was previously treated with PCP in an open-vat, thermal process until 2001 when it was re-engineered, and an ambient air vapour condensation system was installed to collect and condense PCP vapour emissions, which were recycled into the dip tank.

- In 2000, complaints were received from a nearby school of odours, eye and throat irritation, headaches and nausea. Similar symptom were reported from residents of a bordering community and there was concern over reports of excess cancer rates among current and future teachers at the school.

- Outdoor air sampling produced results of 0.01 to 0.63$\mu g/m^3$, highest in the vicinity of the treatment area except on one sampling day when higher levels (1.48$\mu g/m^3$) were detected at a home downwind of the plant. Indoor air monitoring at the school detected no contaminants but was not conducted when the school was downwind of the plant.

- Onsite surface soil concentrations of 6 contaminants were higher than reference values, and in subsurface soil were higher at lower levels Reference values were exceeded for As, benzanthracene, benzo(b)fluoranthrene, dibenzoanthracene, PCP and As. 1 sample was tested for dioxins and furans, which were detected at levels lower than health-based reference values.

- Offsite soils samples contained contaminants at levels less than reference values

- Contaminants were detected in 1 well (groundwater), but 3 wipe samples for SVOC were negative at the school.

- It was concluded the exposure pathways were present in the soil, river sediment, air, and that there was potential exposure through drinking of groundwater, skin contact with river water and consumption of fish from the river etc.

- An examination of the local cancer registry found that the overall Cancer incidence was in the expected range for the state, but that there was an increased rate of sarcoma's in the 3 zip code areas represented in the review. There was evidence of an association between exposure to industrial graded PCP and soft tissue sarcoma's.

- Recommendations included

    - Restricting access to the site

    - Measures to ensure that workers did not track contaminants home with them

    - A survey of wells in the area

    - Further investigation into the sarcoma cases in the region as well as other cancers among school employees.

13. **Popile Inc, Arkansas**

- The treatment facility operated between 1947 and 1982, utilizing creosote and PCP.

- Sampling revealed onsite contamination (soil, groundwater) with volatile organic compounds, PAH's, phenols, furans, dioxins and metals onsite, as well as contamination of surface water and sediment in the adjacent bayou.

- It was concluded that there was potential exposure to previous workers and others onsite through inhalation of vapours, incidental visitors by ingestion and soil contact, and through ingestion of fish caught in the bayou area.

- The area was classified as an indeterminate health hazard, as there was insufficient information about past levels of exposure. It could, in the future, pose a health hazard if the site was developed for future residential and commercial use and onsite wells were used for drinking water.

- Levels of BaP, As and Cr as well as dioxins were elevated in waste sludge and surface soil; post-remediation these dropped to below detectable levels with the exception of PCP, which was within the CREG used as reference level, and TCDD, which still exceeded the CREG. Level of contaminants exceeded reference levels in subsoil as well and although lower post-remediation, still exceeded reference levels for BaP, PCP and TCDD.

  Groundwater levels of Benzene, toluene, BaP, PCP and As exceeded reference levels.

14. **Conroe, Texas**

- Plant operated 1946-1997, utilizing creosote, PCP and CCA.

- In 2002, the EPA removed contaminated soil and sediment from the site and surrounding creeks etc, storing it in an impermeable vault constructed onsite.

- On a subsequent 2002/2003 site visit, a strong smell of creosote was noted.

- Pre-remediation sampling of onsite soil, surface water and groundwater indicated severe contamination.

- Groundwater contamination was not widespread; as wells in the area were not used for drinking or household use, it was not considered a public health hazard

- It was considered that volatilization of contaminants was likely to have occurred during remediation operations, hence the odour on the site visit. However, ongoing volatilization would be prevented by the polyethylene cap on the vault, constructed of 3 foot compacted clay.

- It was concluded that past exposure to downstream sediment and soil may have been a health hazard as well as onsite soil, but the hazard had been mitigated during remediation. Onsite groundwater was considered not a hazards as it was not for drinking, and past exposure to airborne contaminants an indeterminate hazard.

- Community concerns were:

- The safety of drinking water
- The potential for exposure during flooding
- An increased cancer risk. A review of the cancer registry showed a modest but statistically significant increase of cancers of the lung and bronchus among men, and breast among women, but it was felt that these were likely to be related to the effects of smoking and family history.

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The age-and gender-adjusted difference in the scoring of symptoms ranged from 0.8 (eye irritation; 4.2 vs 3.4 in child cases and controls respectively) to 4.5 (dryness of mouth nose or throat and skin redness, dryness or itching; 6.6 vs 2 of child cases and controls respectively).

(17.8% in cases vs 5.8% in controls; $p<0.0001$, i.e greater than 99.9%significance)

(21.7% vs 4.3%; $p<0.0001$)

(40.5% vs 11%; $p<0.0001$)

Among adults these were significant for sway speed (eyes closed), simple reaction time, choice reaction time, trails and peripheral fields, as well as grip strength, low-frequency median nerve and low and high frequency trigeminal nerve testing. Among children, differences between cases and controls were significant only for sway speed (eyes closed) and peripheral field.

Cases had statistically significantly lower proportions of lymphocytes, lower white cell counts and serum globulin levels, lower platelets and differences in red blood cell parameters
.

Toxic equivalents

Polycyclic aromatic hydrocarbons

octachlorodibenzo-*p*-dioxin

hexachlorodibenzo-*p*-dioxin

Arsenic

Benzo-(a)-pyrene

Public Health Hazard

National Priority List