Office of Environmental Health Hazard Assessment

George V. Alexeeff, Ph.D., D.A.B.T., Director
Headquarters • 1001 I Street • Sacramento, California 95814
Mailing Address: P.O. Box 4010 • Sacramento, California 95812-4010
Oakland Office • Mailing Address: 1515 Clay Street, 16th Floor • Oakland, California 94612

Matthew Rodriquez
Secretary for
Environmental Protection

Edmund G. Brown Jr.
Governor

MEMORANDUM

TO: Debbie Raphael
Director
Department of Toxic Substances Control
1001 I St., 25th floor
Sacramento, CA 95814

VIA: Allan Hirsch
Chief Deputy Director
Office of Environmental Health Hazard Assessment
1001 I St., 25th floor
Sacramento, CA 95814

FROM: David Siegel, Ph.D., Chief
Air, Community, and Environmental Research Branch
Office of Environmental Health Hazard Assessment
1001 I St., MS-12B
Sacramento, CA 95814

DATE: November 26, 2013

SUBJECT: EVALUATION OF SAMPLING RESULTS FROM THE AUTUMNWOOD COMMUNITY IN WILDOMAR, CALIFORNIA

Attached per your request is a report from the Office of Environmental Health Hazard Assessment (OEHHA) on the evaluation of data on the environmental investigation of the Autumnwood development in Wildomar, California. The information and data came from the binder of compiled information that your office sent to us as well as other information received at our meetings. The evaluation was to determine if environmental contaminants may explain the cause of the reported symptoms and illnesses of the residents in the Autumnwood development.

If you have any questions, please do not hesitate to call me at 916-322-5624 or david.siegel@oehha.ca.gov.

Attachment

cc: William S. Bosan, Ph.D.
Senior Toxicologist
Southern California Unit Chief
Human and Ecological Risk Office
Brownfields and Environmental Restoration
Department of Toxic Substances Control
9211 Oakdale Avenue
Chatsworth, CA 91311

Gabriele Windgasse, DrPH
Chief, Site Assessment Section
Environmental Health Investigations Branch
California Department of Public Health
850 Marina Bay Parkway, Bldg. P
Richmond, CA 94804

Evaluation of the Health Implications from Measured Environmental Contaminants in the Autumnwood Development

Office of Environmental Health Hazard Assessment

The residents of the Autumnwood residential development located in Wildomar, California, have expressed concern about excessive exposures to chemical contaminants from soil on which their homes are built. A number of residents have complained of illnesses that have occurred after moving into their homes in this new development that opened in 2006. Some of the illnesses occurred within months of moving in to the homes. A large list of illness complaints has been compiled by the residents. Many of the illness complaints seem to be the result of irritants and include eye irritation, lung congestion, throat irritation, stuffy or runny noses, rashes, skin dryness or redness. More serious complaints include exacerbated or new on-set asthma, abdominal pain, muscle pain, numbness in the extremities, face and lips, autoimmune disorders, and tremors. Two residents have died unexpectedly.

The residents are concerned that the soil brought in to grade the subdivision was contaminated and has led to the illnesses. The fill soil was reported to have come from the Ranch California Water District, which had excess soil from the construction of their Recycled Storage Pond No. 5. Six borings were taken at the pond site and there were no notations in the boring logs of hydrocarbon or chemical odors or stains. In addition, some homes have been found to have possible construction defects with water infiltration through their slab foundations.

A number of analytical studies have been conducted to determine the concentration of chemicals contaminants in the soil, ambient air, indoor air, and soil gas. The Office of Environmental Health Hazard Assessment (OEHHA) was asked to help interpret the findings of the studies in terms of potential health implications to the residents. This report evaluates whether the levels found in the environmental media are sufficiently elevated to explain the reported illnesses. This report is not a risk assessment.

The evaluation looked at indoor air monitoring and soil gas monitoring performed or overseen by the residents' consulting industrial hygienist, Nancy Carraway, and indoor air monitoring performed by the South Coast Air Quality Management District (SCAQMD).

Ms. Carraway had prepared a table of results from selected air samples taken from 12 homes in the development and selected chemicals from the suite of chemicals sampled. These sampling results were evaluated for the hazard that the chemicals may pose to a person exposed to the concentrations of chemicals in a residential setting. The indoor air samples taken by the SCAQMD were similarly evaluated.

The subsurface soil gas samples were evaluated for the hazard the chemicals may pose in a residential setting using the assumption that the volatile chemicals would infiltrate the homes' indoor air from below the foundation of the homes.

Environmental Concentrations Measured

The residents' consultant provided to state representatives a summary table of the levels of seven chemical contaminants found in the indoor and outdoor air of 12 homes in the Autumnwood Development. That summary table is presented as Table 1 below and was modified to give the date sampling occurred and the street name of the residence in place of the resident's name. Eight of the homes sampled are located on Amaryllis Court with the others on parallel streets. Sampling dates cover the period between late May 2012 and early January 2013.

The table presents only a small number of the chemicals actually measured in the air and only a small number of samples actually taken. The consultant may have chosen these chemicals because they are all classified as carcinogens and pose a cancer risk at low concentrations. She may have chosen these samples as representative of samples taken during the six-month course of the investigation.

Table 1. Samples Taken in 12 Homes in the Autumnwood Development [a]

Location	Date Sampled	Vinyl chloride	Carbon tetrachloride	Benzene	1,2-Dichloro-ethane	Trichloro-ethylene	Tetrachloro-ethylene	Ethylbenzene
		μg/m³						
Amaryllis Court 1	5/29/2012							
Kitchen subfloor		ND[b]	0.56	4.5	1.4	0.062	0.18	1.2
Corridor outside laundry		ND	0.58	2.0	2.1	ND	ND	0.97
Outside		ND	0.58	0.41	0.088	ND	0.086	0.16
Amaryllis Court 2	7/10/2012							
Under ground floor		ND	0.50	2.4	0.30	ND	0.16	4.7
Blue/brown bedroom		ND	0.65	1.5	1.0	ND	ND	1.7
Outside		ND	0.60	0.43	0.056	ND	ND	0.23
Amaryllis Court 3	7/10/2012							
Guest room		ND	1.6	1.5	12	ND	ND	1.6
Drum room		ND	1.7	3.1	7.4	ND	ND	2.5
Outside		ND	0.57	0.39	0.084	ND	ND	0.24
Amaryllis Court 4	8/15/2012							
Master bedroom: 2nd floor		0.026	0.76	1.4	4.1	1.4	0.71	4.2
Downstairs bedroom		0.031	0.67	2.0	0.89	0.07	0.22	2.5
Outside		0.0047	0.60	0.47	0.041	0.029	0.12	0.30
Amaryllis Court 5[c]	9/25/2012							
Guest bedroom		0.0080	0.95	2.9	0.78	0.050	0.15	3.8
Den/playroom		0.0063	0.81	1.7	0.39	0.037	0.14	2.3
Outside		ND	0.62	0.45	0.065	0.055	0.12	0.36

Location	Date Sampled	Vinyl chloride	Carbon tetrachloride	Benzene	1,2-Dichloro-ethane	Trichloro-ethylene	Tetrachloro-ethylene	Ethylbenzene
		μg/m³						
Amaryllis Court 6[c]	9/25/2012							
Sewing room			0.59	0.45	0.07	0.012	0.06	0.21
Extra bedroom		0.0050	0.62	1.0	0.96	0.151	0.69	1.5
Outside		ND	0.66	0.76	1.6	0.24	1.4	3.0
Amaryllis Court 7[c]	9/25/2012							
Grandmother's bedroom		0.021	0.68	1.7	0.92	0.043	0.12	1.4
Master bedroom, 2nd floor		ND	0.68	4.1	2.9	0.027	0.24	3.4
Outside		ND	0.62	0.45	0.065	0.011	0.060	0.27
Amaryllis Court 8[c]	9/25/2012							
Master bedroom, 2nd floor		0.017	0.68	0.52	2.4	0.050	0.17	1.8
Laundry room		0.010	0.68	0.86	2.0	0.052	0.080	1.7
Outside		0.0052	0.60	0.45	0.070	0.012	0.057	0.30
Front Street 1	8/15/2012							
Office		0.019	0.59	0.99	39	0.032	0.091	0.68
Bedroom		0.0091	0.63	1.1	11	0.49	0.58	2.4
Outside		0.005	0.64	0.51	0.052	0.027	0.14	0.48
Pink Ginger Court	10/11/2012							
Guest bedroom - 2nd floor		ND	ND	0.95	8.9	ND	ND	1.6
Mom's bedroom - 1st floor		ND	ND	1.0	3.7	ND	ND	ND
Outside by waterfall		ND	ND	ND	ND	ND	ND	ND
Protea Court	10/11/2012							
Fish tank room		ND	ND	0.85	4.6	ND	ND	ND
Spare bedroom		ND	ND	1.6	4.1	ND	ND	2.7
Outside		ND	ND	2.3	ND	ND	ND	ND
Front Street 2	1/2/2013							
Family room		ND	ND	2.4	1.3	ND	ND	2.3
Master bedroom		ND	ND	2.2	1.8	ND	ND	2.2
Outside		ND	ND	1.3	ND	ND	ND	ND

[a] Some samples had detectable concentrations between the minimal detection level and the reportable level meaning the accuracy of the results has more uncertainty than those concentrations above the reportable level. All detectable concentrations were used in the evaluation.

[b] ND=non-detectable chemicals

[c] The sampling results were reported in the units parts per billion by volume (ppbv) in the consultant's summary table and were converted to units μg/m³ in this table to be consistent with the other sampling results.

Measures of Risk for Comparison: Target Indoor Air Concentrations

In order to evaluate the health hazard that may be presented by the chemicals found in the homes, a list of target indoor air concentrations (TIACs) for the chemicals was obtained from an existing list of TIACs that OEHHA used to calculate California Human Health Screening Levels (CHHSLs), or the TIACs for chemicals without CHHSLs were calculated using the same methodology (OEHHA, 2005). A TIAC for a carcinogen is based on a lifetime risk from exposure of one in a million, 10^{-6}. A TIAC for a non-carcinogen is the highest concentration that should pose no significant health hazard if exposure is to that one chemical alone and there are no other exposures. A fuller explanation of TIACs and CHHSLs is given in an appendix at the end of the report.

To determine if there is a potential health issue with the air concentration of a chemical, that concentration is divided by the TIAC. This ratio is called the risk quotient for a carcinogenic effect and a hazard quotient for a non-carcinogenic effect. Any ratio over one is of potential concern because it indicates the chemical may pose a carcinogenic risk of greater than 10^{-6} or a potential hazard for a non-cancer health effect.

The evaluation was done for the air concentrations found in the homes, shown in Table 2, and the air concentrations found outside the home on the same day, shown in Table 3. The risk and hazard quotients for maximum, minimum, median, and average of the detected concentrations for each chemical were calculated.

Cancer Risk Ratios and Non-Cancer Hazard Quotients at Measured Indoor and Outdoor Air Levels

Table 2 shows that for each maximum chemical concentration the cancer risk quotient was over one, indicating risks greater than one per million. Two measured chemicals – carbon tetrachloride and benzene -- were above the risk quotient of one for all four concentrations – minimum, max, median and average. Four measured chemicals were above the risk quotient of one for three of the concentrations – maximum, median and average. 1,2-Dichloroethane had a very high maximum concentration, while the minimum concentration detected was below the level of concern. Ethylbenzene, while above the level of potential concern, was never at the level of concern as the other three chemicals.

The hazard quotient for non-cancer effects were below the level of concern for each chemical even for the maximum concentrations detected.

Exposure to multiple chemicals at one time may increase the carcinogenic risk and non-carcinogenic hazard to the residents. The influence one chemical may have on the health effect of another chemical is not well understood for most chemicals combinations. The interaction can greatly increase the individual chemical's actions, simply add to each other's effect, or actually protect against the effect of another chemical. Generally the cancer risks for each chemical are assumed to be additive in determining the overall cancer risk of the mixture. Similarly, hazard indices for individual chemicals can be added in screening analyses as a measure of non-cancer impacts. In Table 2, the risk indices are well over one and indicate risk estimates of greater than one in 100,000 or more, while the hazard indices are below one.

The outdoor concentrations detected generally give the same pattern of risk quotients as indoor air but were lower as shown in Table 3. Benzene, carbon tetrachloride and 1,2-dichloroethane were again the chemicals of most concern and made up the greatest portion of the risk indices. Again, the hazard quotients and indices used to characterize non-cancer risks were below the level of concern.

While the findings are based on only some of the sampling done, they indicate that the biggest issue from exposure to the chemicals is long-term cancer risk and not short-term or long-term non-cancer hazards. As discussed below, further investigations that were done do raise the question on the potential for non-carcinogenic hazard from exposures.

Table 2. Risk/Hazard Quotients of the Maximum, Minimum, Median and Average Indoor Air Concentrations of Seven Chemicals found in12 Homes in the Autumnwood Development

Chemical	n[a]	Risk Quotient Based on Carcinogenic Effect					Hazard Quotient Based on Non-carcinogenic Effect				
		TIACc[b] µg/m³	Maximum Concentration	Minimum Concentration	Median Concentration	Average Concentration	TIACnc[c] µg/m³	Maximum Concentration	Minimum Concentration	Median Concentration	Average Concentration
Vinyl chloride	10	0.031	1.0	0.16	0.44	0.49	100	0.00031	0.000050	0.00014	0.00015
Carbon tetrachloride	18	0.058	29	8.6	12	13	42	0.0405	0.012	0.016	0.018
Benzene	24	0.084	54	5.3	18	21	63	0.071	0.0071	0.025	0.028
1,2-Dichloroethane	24	0.12	330	0.55	17	40	420	0.093	0.00016	0.0049	0.011
Trichloroethylene	13	1.2	1.2	0.01	0.042	0.16	630	0.0022	0.000018	0.000080	0.00030
Tetrachloroethylene	14	0.41	1.7	0.14	0.40	0.62	37	0.019	0.0016	0.0044	0.0069
Ethylbenzene	22	0.97	4.8	0.22	2.1	2.2	2100	0.0022	0.00010	0.0010	0.0010
Risk/Hazard Index[d]			420	15	50	78		0.23	0.021	0.051	0.066

[a] Number of samples with detectable concentrations of the chemical out of the 24 indoor air samples taken. Some samples had detectable concentrations between the minimal detection level (MDL) and the reportable level (RL) meaning the accuracy of the results has more uncertainty than those concentrations above the RL. All detected concentrations were used in the evaluation.

[b] TIACc is the Target Indoor Air Concentration for the carcinogenic effect of the chemical.

[c] TIACnc is the Target Indoor Air Concentration for the non-carcinogenic effect of the chemical.

[d] The sum of the individual chemical risk or hazard quotients.

Table 3. Risk/Hazard Quotients of the Maximum, Minimum, Median and Average Outside Air Concentrations of Seven Chemicals found Outside12 Homes in the Autumwood Development

Chemical	n[a]	Risk Quotient Based on Carcinogenic Effect					Hazard Quotient Based on Non-carcinogenic Effect				
		TIACc[b] $\mu g/m^3$	Maximum Concentration	Minimum Concentration	Median Concentration	Average Concentration	TIACnc[c] $\mu g/m^3$	Maximum Concentration	Minimum Concentration	Median Concentration	Average Concentration
Vinyl chloride	3	0.031	0.17	0.15	0.16	0.16	100	0.000052	0.000047	0.000050	0.000050
Carbon tetrachloride	9	0.058	11	9.8	10	11	42	0.016	0.014	0.014	0.015
Benzene	11	0.084	27	4.6	5.3	8.6	63	0.037	0.0062	0.0071	0.011
1,2-Dichloroethane	9	0.12	13	0.34	0.55	2.0	420	0.0038	0.00010	0.00016	0.00056
Trichloroethylene	6	1.2	0.20	0.0092	0.023	0.052	630	0.00038	0.000017	0.000044	0.00010
Tetrachloroethylene	7	0.41	3.4	0.14	0.28	0.69	37	0.037	0.0015	0.0032	0.0076
Ethylbenzene	9	0.97	3.1	0.16	0.31	0.61	2100	0.0014	0.000076	0.00014	0.00028
Risk/Hazard Index[d]			59	15	17	23		0.095	0.021	0.025	0.034

[a] Number of samples with detectable concentrations of the chemical out of the 12 outdoor air samples taken. Some samples had concentrations between the minimal detection level and the reportable level meaning the accuracy of the results has more uncertainty than those concentrations above the reportable level. All detected concentrations were used in the evaluation.

[b] TIACc is the Target Indoor Air Concentration for the carcinogenic effect of the chemical.

[c] TIACnc is the Target Indoor Air Concentration for the non-carcinogenic effect of the chemical.

[d] The sum of the individual chemical risk or hazard quotients.

Risk Ratios and Hazard Quotients Associated with SCAMQD Measurements

The South Coast Air Quality Management District (SCAQMD) did indoor air sampling of three homes in the Autumnwood development (SCAQMD, 2013). Most of the samples were "grab" samples, where the air container is filled quickly. One sample was taken over a three-hour period, which tends to average the chemical concentrations in the air and would not capture large spikes over a short period of time. Table 4 shows the concentrations of most of the same chemicals listed in Table 1. The difference is the absence of vinyl chloride and the addition of 1,2-dibromoethane in Table 4. Vinyl chloride was not detected in the SCAQMD sampling and therefore is not reported in Table 4. However, the SCAQMD did detect 1,2-dibromoethane at significant concentrations. 1,2-Dibromoethane was not detected in the sampling reported in Table 1.

Table 4. Samples Taken in 3 Homes in the Autumnwood Development by the South Coast Air Quality Management District[a]

	Date Sampled	Sample Type	Benzene	Carbon tetrachloride	1,2-Dichloro-ethane	1,2-bromo-ethane	Trichloro-ethylene	Tetrachloro-ethylene	Ethylbenzene
			μg/m³						
Amaryllis Court 4									
family room	1/2/2013	Grab	2.1	0.68	0.87	6.6			1.4
master bedroom	1/2/2013	Grab	2.1	0.68	0.87	5.0			1.4
Front Street 2									
living room	1/2/2013	Grab	4.1	0.68	1.3	12		0.73	3.3
master bedroom	1/2/2013	Grab	3.8	0.68	1.7	11	0.58	0.73	3.3
Amaryllis Court 1									
living room	1/2/2013	Grab	2.1	0.68	0.44	3.3	<0.58		0.47
master bedroom, second floor	1/2/2013	Grab	1.7	0.68	0.44	3.3			0.47
living room	1/15/2013	Grab	1.3	0.68					<0.47
living room	1/15/2013	3 hour	1.3	0.74	<0.44				<0.47

[a] The sampling results were reported in parts per billion volume (ppbv) in the consultant's summary table and were converted to μg/m³ in this table to be consistent with the other sampling results.

The risk and hazard quotients calculated for the indoor concentrations are shown in Table 5. Benzene, carbon tetrachloride, and 1,2-dichloroethane were again found to have risk quotients well above one, similar to the consultant's sampling results. The risk quotient for tetrachloroethylene is also high, but was only found in one of the homes. 1,2-dibromoethane concentrations also gave higher risk quotients. However, 1,2-dibromoethane concentrations also gave high hazard quotients while the other chemical concentrations gave hazard quotients well below the level of potential concern.

There are questions with the findings for 1,2-dibromoethane. Although it was detected in all grab samples taken on the same day (12/2/2012), 1,2-dibromoethane was not detected in the grab sample and the 3-hour sample taken in one of the same homes almost 2 weeks later (12/15/2012). In addition, the other sampling done by the residents' consultant did not detect 1,2-dibromoethane in any sample, even though the reporting limit for the analysis was much lower than concentrations detected in the grab samples. Recently, we were informed that the SCAQMD laboratory reevaluated its analysis of 1,2-dibromoethane and determined that the findings of high levels of the chemical are likely erroneous. Additional investigation may be warranted, especially since the high levels initially reported by SCAQMD are associated with reproductive effects in males.

Table 5. Risk/Hazard Quotients of the Maximum, Minimum and Average Indoor Air Concentrations of Seven Chemicals found in 3 Homes in the Autumwood Development

		Risk Quotient Based on Carcinogenic Effect				**Hazard Quotient Based on Non-carcinogenic Effect**			
Chemical	**n[a]**	**TIACc[b] µg/m³**	**Maximum Concentration**	**Minimum Concentration**	**Average Concentration**	**TIACnc[c] µg/m³**	**Maximum Concentration**	**Minimum Concentration**	**Average Concentration**
Benzene	8	0.084	49	16	27	63	0.066	0.021	0.037
Carbon tetrachloride	8	0.058	13	12	12	42	0.018	0.016	0.016
1,2-Dichloroethane	6	0.12	15	3.6	7.9	420	0.0042	0.0010	0.0022
1,2-Dibromoethane	6	1.2	10	2.8	5.7	0.83	15	4.0	8.3
Trichloroethylene	1	0.41	1.4	1.4	1.4	630	0.00092	0.00092	0.00092
Tetrachloroethylene	2	0.034	21	21	21	37	0.020	0.020	0.020
Ethylbenzene	6	0.97	3.4	0.48	1.8	2100	0.0016	0.00022	0.00082
Risk/Hazard Index[d]			110	57	78		15	4.0	8.4

[a] Number of samples with detectable concentrations of the chemical out of the 8 indoor air samples taken. Sample results reported with a less than sign (<) were not included in the evaluation.
[b] TIACc is the Target Indoor Air Concentration for the carcinogenic effect of the chemical.
[c] TIACnc is the Target Indoor Air Concentration for the non-carcinogenic effect of the chemical.
[d] The sum of the individual chemical risk or hazard quotients.

Sampling for formaldehyde indoor air concentrations was done in four homes in the Autumnwood development. Table 6 shows the sampling results. The table also shows the risk and hazard quotients based on the concentrations. The risk quotients are well above the level of potential concern for formaldehyde exposure, as were the hazard quotients. In two homes, the concentrations were above the acute reference exposure level. These findings suggest that residents would find the indoor air to be irritating to their respiratory system and cause some of the symptoms reported by the residents.

Table 6 Formaldehyde Concentrations and Their Risk and Hazard Quotients for 4 Homes on Amaryllis Court in Autumnwood

Location	Date Sampled	Formaldehyde Conc. (µg/m³)	TIACc[a] 0.41 µg/m³	TIACnc[b] 9.0 µg/m³	Acute[c] 55 µg/m³
			Risk/Hazard Quotient		
Amaryllis Court 3 Inside	10/22/2012	50	120	5.6	0.91
Amaryllis Court 4 Inside	10/22/2012	66	160	7.3	1.2
Amaryllis Court 2 Outside	10/22/2012	4.8	12	0.53	0.087
Amaryllis Court 2 Inside	10/22/2012	23	56	2.6	0.42
Amaryllis Court 1 Inside	10/22/2012	82	200	9.1	1.5

[a] TIACc is the Target Indoor Air Concentration for the carcinogenic effect of the chemical.
[b] TIACnc is the Target Indoor Air Concentration for the non-carcinogenic effect of the chemical.
[c] Acute is the Reference Exposure Level for a one hour exposure to formaldehyde.

It must be noted, however, that formaldehyde is commonly found in home indoor air. Many building products contain urea-formaldehyde resins that off-gas formaldehyde, so newer homes are expected to have more formaldehyde in indoor air. Over time, the off-gassing deceases and the formaldehyde levels are expected to decrease. Remodeling and new furniture may also be sources of formaldehyde in older homes.

An average formaldehyde level for existing homes is around 22 micrograms per cubic meter of air (µg/m³)(Gordon et al., 1999; Weisel et al., 2005). A recent report tested 105 new homes in California (Offermann, 2009). It found levels of formaldehyde to range from 4.8 to 136 µg/m³, with an average level of 43 µg/m³ and a median level of 36 µg/m³. Three of the homes tested on Amaryllis Court were above the average level for new homes, although the homes on Amaryllis Court are six or seven years old and would be expected to have lower levels. .

Comparison of Autumnwood Homes with Other Homes

A study was identified where 100 homes were sampled in each of three cities with different air pollution sources and weather conditions: Los Angeles, Houston, and Elizabeth, NJ. The homes were selected by distance from various pollution sources and sampled during two 48-hour periods in different seasons between the summer of 1999 and the spring of 2001 (Weisel et al., 2005).

A large study in California was also identified where more than 100 new homes were sampled for indoor air contaminants. The study measured indoor air chemical concentrations in new homes in various locations in California. This study was done because concerns have been raised regarding whether homeowners use windows, exhaust fans, and other mechanical ventilation devices enough to remove indoor air contaminants and excess moisture (Offermann, 2009).

Comparisons of indoor contaminant levels were made between the Autumnwood homes and homes in the Weisel study, which were located in cities known for air pollution problems. In addition, although the homes in the Autumnwood development are not considered new, a comparison was also made of indoor air contaminant concentrations found in the Autumnwood homes to concentrations found in the Offermann study because the Offermann study provides the most recent information available. New homes would be expected to have higher levels of volatile chemicals than older homes because of the new materials used in the construction of the homes. Over time, the levels would be expected to decrease somewhat. So the levels of chemicals found in the Autumnwood homes are not expected to be greater than in the new homes measured in the Offermann study.

The number of chemicals measured in the Offermann and Weisel et al. studies was fewer than measured in the Autumnwood development homes. The comparison of indoor air contaminant concentrations was done on the chemicals that were common to all sets of data. Autumnwood development samples used for the comparison were the same samples identified in Table 1.

Table 7 shows the values found in new homes from the Offerman study, existing homes in the Weisel et al. study, and the homes in the Autumnwood development. While the comparison is limited based on the number of chemicals compared, it is clear that the levels found in the homes in the Autumnwood development are not greatly different than levels found in homes measured in the two studies. In many cases the means and the 50th percentile concentrations are actually somewhat higher in the Autumnwood homes than the new homes measured in the Offermann study. Similarly, the 50th percentile concentrations for a number of chemicals were higher in the Autumnwood homes than in the homes of the Weisel et al. study. No specific conclusions can be drawn from these comparisons because there were many fewer homes studied in the Autumnwood development than the two cited studies. The homes in the Offerman and Weisel et al. studies are expected to have higher than normal indoor concentrations of chemical pollutants because of their age and location. The Autumnwood homes had similar or somewhat higher concentrations, which suggests there may be an unusual source for the chemicals. But further investigation would be needed to determine if such a source exists.

Table 7 Comparison of indoor contaminant levels (μg/m^3).

			Mean[c]		Percentiles[d]				
Compound	**Study[a]**	**n[b]**	**Arithmetic**	**Geometric**	**10%**	**25%**	**50%**	**75%**	**90%**
Benzene[d]	O	107	1.6	0.8	0.1	0.1	1.1	2	4.3
	W	554	3.5	NA[g]	NA	NA	2.2	NA	NA
	A	**22**	**1.6**	**1.4**	**0.85**	**0.97**	**1.5**	**2.0**	**2.7**
Chloroform	O	107	0.7	0.4	0.2	0.2	0.2	0.7	1.8
	W	554	1.9	NA	NA	NA	0.92	NA	NA
	A	**22**	**1.2**	**0.93**	**ND**	**0.31**	**0.72**	**1.1**	**1.9**
Styrene	O	107	1.8	0.9	0.2	0.6	0.9	1.8	2.8
	W	554	1.4	NA	NA	NA	0.50	NA	NA
	A	**22**	**2.4**	**1.8**	**ND**	**0.89**	**1.7**	**2.9**	**4.1**
Tetrachloro-ethylene	O	107	0.6	0.3	0.2	0.2	0.2	0.3	0.6
	W	554	1.8	NA	NA	NA	0.56	NA	NA
	A	**22**	**0.27**	**0.19**	**ND**	**ND**	**0.070**	**0.16**	**0.55**
Toluene	O	107	17	9.5	3	4.8	8.5	18	42
	W	554	15	NA	NA	NA	10.1	NA	NA
	A	**22**	**12**	**9.2**	**1.6**	**6.9**	**11**	**16**	**19**
m,p-Xylene	O	107	7.1	4.2	1.4	2.3	4.2	9.2	15
	W	554	7.3	NA	NA	NA	4.1	NA	NA
	A	**22**	**6.2**	**5.0**	**2.0**	**3.2**	**5.8**	**8.2**	**10**
o-Xylene	O	107	2.1	1.1	0.1	0.6	1.2	2.7	4.7
	W	554	2.5	NA	NA	NA	1.5	NA	NA
	A	**22**	**2.4**	**2.1**	**0.44**	**1.3**	**2.1**	**2.9**	**4.0**
Formaldehyde	O	105	43	36	14	25	36	58	86
	W	398	22	NA	NA	NA	20	NA	NA

[a] O = Offerman study; W = Weisel et al. study; **A** = Autumnwood study

[b] For the Offerman study, n equals the number of homes sampled (107). For the Weisel et al. study n equals the number of samples evaluated. For the Autumnwood development homes, n equals the number of samples evaluated (22). The samples used are from those listed in Table 1, except for the samples identified as coming from under the slab.

[c] The arithmetic and geometric means were calculated. For the Autumnwood homes non-detect levels were excluded from the calculation.

[d] Percentiles were calculated for the levels found in the homes. For the Autumnwood homes, non-detect levels were included in the calculations.

[e] The two rows for each compound represent the sources of data. The top row is from the Offermann study (2009). The bottom row is from the Autumnwood development data.

[f] ND = not detected

[g] NA = not available

Results of Soil and Sub-slab Gas Samples

While building materials, home furnishings and cleaning products may account for chemicals found in the indoor air, the residents of the Autumnwood development have concerns that chemicals may also be from contaminated soil used as engineered fill for their homes' construction. Soil gas was collected from borings in the front yards of seven homes on Amaryllis Court (Ami Adini & Associates, 2012). The soil gas was collected at a depth of five and/or 10 feet and at 15 feet in one instance. Sixteen samples were taken. Of the 63 analytes tested for, only six were detected and are listed in Table 8. When the highest concentrations of each chemical was compared to the soil gas CHHSL, using the same methodology of calculating a risk/hazard quotient, none of the chemicals appeared to be above the level of potential concern. Being above the level of potential concern would mean the chemical was in soil gas at a level that could potentially infiltrate through the soil and foundation of a home and reach an indoor air level high enough to surpass the TIAC. This finding suggests that the soil is not sufficiently contaminated with volatile chemicals in the area of Amaryllis Court to pose an indoor air problem to the residents.

Table 8 Subsurface Soil Gas Samples Taken in the Front Yard of 7 Homes on Amaryllis Court

Chemical[a]	n[b]	Concentration Range (μg/m^3)	CHHSL (μg/m^3)	Risk/Hazard Quotient[c]
Chlorobenzene	1	66	1,200,000	0.000055
Chloroform	1	150	420	0.35
Chloromethane	1	390	77,600	0.005
Toluene	10	18-48	320,000	0.00015
Trichloroethylene	4	31-40	1,300	0.031
Trichloroflouromethane	4	11-69	320,000[d]	0.00022

[a] Only chemicals detected were included in this list.
[b] n is the number of times the chemical was detected in the 16 samples taken.
[c] The risk/hazard quotient was calculated using the highest concentration of the chemical detected.
[d] A CHHSL for trichloroflouromethane could not be calculated because no adequate reference exposure level could be found. The CHHSL for toluene was use as a substitute.

In addition to soil gas samples, sub-slab samples were taken from two homes by two investigators, Ami Adini & Associates and Nancy Carraway, the residents' consultant. The sampling results and evaluations are in Table 9. The two samples analyzed by Air Technology Laboratories, Inc., for Nancy Carraway, are the same samples listed first for location Amaryllis Court 1 and Amaryllis Court 2 in Table 1 and were evaluated as indoor air samples. However, in Table 1, the samples are identified as coming from under the kitchen floor or slab and so are also included here.

The samples were analyzed by two different laboratories, Jones Environmental, Inc. (JE), which had a minimal detection limit of 8 μg/m^3 for all analytes, and Air Technology Laboratories, Inc. (ATL), which had reporting levels much lower and variable. The samples analyzed by JE had a number of analytes below the reporting level which were found at lower concentrations in the ATL analyses.

Table 9 Sub-Slab Samples Taken at Two Homes on Amaryllis Court

Analytical Lab	Jones Environmental, Inc.				Air Technology Laboratories, Inc.				Sub-Slab CHHSL
Home	Amaryllis Court 1		Amaryllis Court 2		Amaryllis Court 1		Amaryllis Court 2		
Date Sampled	9/12/2012		9/12/2012		5/29/2012		7/10/2012		
Chemical	μg/m^3	R/H Quot.[a]	μg/m^3	R/H Quot.	μg/m^3	R/H Quot.	μg/m^3	R/H Quot.	μg/m^3
Chloroform	63	**6.8**	ND		3.7	0.40	0.46	0.05	9.2
Chloromethane	ND[b]		ND		0.28	0.00015	12	0.0063	1,900
Toluene	22	0.0035	15	0.0024	9.9	0.0016	41	0.0065	6,300
Trichloroethylene	ND		ND		0.062	0.0026	ND[c]		24
Trichlorofluoro-methane	ND		ND		1.4	0.00022	1.3	0.00021	6,300[e]
Benzene	40	**24**	ND		4.5	**2.6**	2.4	**1.4**	1.7
Naphthalene	62	**44**	ND		N/A[d]		N/A		1.4
Styrene	119	0.0063	ND		2	0.00011	1.5	0.000079	19,000
Carbon Tetrachloride	ND		ND		0.56	0.47	0.5	0.42	1.2
1,2-Dichloroethane	ND		ND		1.4	0.61	0.3	0.13	2.3
Tetrachloroethylene	ND		ND		0.18	0.022	0.16	0.020	8.2
Ethylbenzene	ND		ND		1.2	0.063	4.7	0.25	19

[a] R/H Quotient.=Risk/Hazard Quotient calculated by dividing the sub-slab chemical concentration by the sub-slab CHHSL.
[b] ND=Not Detected-The minimal detection limit for Jones Environmental, Inc.is at 8 μg/m^3 for all analytes.
[c] ND=Not Detected-The reporting limit for AirTechnology Laboratories, Inc. varied and was 0.11 μg/m^3 in this analysis.
[d] N/A means the chemical was not measured.
[e] A sub-slab CHHSL for trichloroflouromethane could not be calculated because no adequate reference exposure level could be found. The sub-slab CHHSL for toluene was use as a substitute.

The sub-slab sample from the home designated Amaryllis Court 1 and analyzed by JE had concentrations of three chemicals at levels of potential concern: chloroform, benzene and naphthalene. A sample taken earlier from the home and analyzed by ATL only identified benzene as a chemical of potential concern and it was almost 10 fold lower in concentration. All other chemicals listed in Table 9 were below a level of concern. There are a number of variables that can affect the results including methods used in sample collection and analysis as well as the time of year the samples were taken.

Discussion and Conclusions

This evaluation was at a screening level to determine if there was evidence of environmental contamination in the Autumnwood development that might explain illnesses reported by the residents. The indoor concentrations of chemical contaminants do present a potential concern for long-term carcinogenic risk. Most of the chemicals evaluated did not present a concern for non-carcinogenic health effects. The chemical concentrations are comparable to levels in existing homes in cities with higher-than-normal air pollution levels and in new homes. While these levels are somewhat higher than might be expected from homes of their age, the mean indoor air concentrations were not at levels of immediate concern, although there were occasional high levels of the chemicals found, but it is not clear if these represent a continuous exposure level.

Two chemicals investigated do raise specific concerns. 1,2-Dibromoethane was found at surprisingly high levels in sampling done by the SCAQMD. It may pose a carcinogenic risk at the levels found and it also poses a potential reproductive hazard to males at these levels. However, further evaluation by the SCAQMD laboratory of the chemical analysis suggests that the findings were erroneous. Additional investigation might be warranted to ensure 1,2-dibromoethane is not present. Other indoor air sampling of the same homes by Nancy Carraway did not detect the chemical even though the level of detection for the analytical method was much lower than the levels found in the homes by the SCAQMD.

Formaldehyde levels were also elevated in three of four homes sampled. The fourth home had a level below that set by the California Air Resources Board Air Quality Guideline. The homes with high levels of formaldehyde were well above the median level found in new homes. Formaldehyde in some homes was at levels where acute effects may occur. Further investigation should be undertaken since limited sampling had been done in these homes. The residents of Autumnwood Development homes have complained about a number of symptoms and illnesses that are similar to those attributed to formaldehyde exposure. OEHHA's Reference Exposure Level document for formaldehyde (2008) states,

> "*As a result of its solubility in water and high reactivity, formaldehyde is efficiently absorbed into the mucus layers protecting the eyes and respiratory tract where it rapidly reacts, leading primarily to localized irritation. Acute high exposure may lead to eye, nose and throat irritation, and in the respiratory tract, nasal obstruction, pulmonary edema and dyspnea. Prolonged or repeated exposures have been associated with allergic sensitization, respiratory symptoms (coughing, wheezing, shortness of breath), histopathological changes in respiratory epithelium, and decrements in lung function. Children, especially those with diagnosed asthma, may be more likely to show impaired pulmonary function and symptoms than are adults following chronic exposure to formaldehyde.*" (OEHHA, 2008).

Sub-surface soil gas sampling does not suggest that the soil is contaminated with volatile chemicals. Even sub-slab sampling in two homes did not indicate high levels of contamination. One home did have high levels of three chemicals in the sub-slab sample, but the other sample at the same house did not and samples from the second home did not confirm a problem with any chemical measured except for possibly benzene. Benzene was just around a level of potential concern for long-term carcinogenic risk in the two homes. Based on the sub-surface sampling and soil analyses of nonvolatile contaminants, not discussed in this report, it is not certain further investigation into contaminated soil will be useful if the sampling and analysis investigation to date is considered adequate.

Indoor air contamination at levels of concern occur frequently in homes because of a variety of sources from outdoor air, indoor construction materials, furnishing materials and products used in the home for everyday living. The evaluation shows that continuous long-term chronic exposures to some of the measured concentrations of some of the contaminants (carbon tetratchloride, benzene, 1,2-dichlorothane, ethylbenzene, and formaldehyde) may be of concern for cancer. For most of the chemicals for which sampling was conducted, there was little concern for non-cancer health effects. The exception is formaldehyde, for which some homes were found with concentrations that gave hazard quotients greater than 1. Follow-up measurements of a representative sampling of the Autumnwood development homes could help indicate which of these potential hazards may be the most significant.

When illnesses, such as cancer, occur in residents exposed to these levels of chemicals for a long time, it is very difficult to associate the illness with a particular exposure. The causes of such chronic illnesses are many, and chronic illnesses are influenced by a diverse set of factors.

While the investigation into the environmental cause of residents' symptoms and illnesses did not find a chemical contaminant basis, except for possible exposure to formaldehyde, other environmental chemicals and causes are still possible. However, the sources and agents are not obvious from the current standard testing that has been done. Since formaldehyde has been found at high levels in a few of the homes and may account for at least some of the symptoms and illnesses reported, further sampling of other aldehydes such as acetaldehyde, acrolein, propionaldehyde, and crotonaldehyde and others, measured in studies by Offerman (2009) and Weisel et al. (2005), would be useful. Finally, because the homes were sampled about six years after the first residents moved in, the current evaluation and any further study cannot address whether symptoms reported by early residents in the Autumnwood development were related to chemical exposures.

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Appendix: California Human Health Screening Levels

In the early 2000s, OEHHA developed a series of California Human Health Screening Levels as a way to quickly assess whether a property may have harmful levels of chemical contaminants in the soil. CHHSLs are soil concentrations of nonvolatile chemicals or soil gas concentrations of volatile chemicals developed using health protective assumptions. They are meant to give an indication if further investigation of a property is needed. If a soil concentration or soil gas concentration is below the CHHSL, the environmental contaminant is unlikely to pose a carcinogenic risk or non-carcinogenic hazard.

A CHHSL is an advisory number, has no regulatory effect, and is published as a reference value that may be used by citizen groups, community organizations, property owners, developers, and local government officials to estimate the degree of effort that may be necessary to remediate a contaminated property.

The screening numbers used in this evaluation should not be used to infer actual health risk of a site. They are based on general assumptions and, therefore, useful to get a general understanding of potential problems with a site, but they cannot be used to assess the actual health risks. Actual health risks can be better estimated with a site-specific health risk assessment, based on OEHHA, Cal/EPA or U.S. Environmental Protection Agency (EPA) guidelines, which is also useful to derive site-specific contaminant cleanup levels.

In the case of the Autumnwood homes, we are primarily interested in the soil gas CHHSLs because of the concern about indoor air concentrations originating from chemical contaminants in the soil. The derivation of the soil gas CHHSL begins with the knowledge that volatile chemicals in the soil are present as gas in air pockets of the soil. They can move through the soil from air pocket to air pocket, but can be slowed in their movement because of interaction with constituents of the soil. Once the volatile chemical reaches the bottom of a home foundation, a small amount can enter the home through small cracks in the foundation.

Models have been developed to estimate how much of a chemical in soil gas will enter a home. The most common model used in the United States to make this estimation is the Johnson and Ettinger model. The model is used to calculate an attenuation factor. This factor provides us with a way to estimate the change that will occur in the concentration of the chemical as it migrates from soil gas five feet below the ground surface to inside the home. In developing the soil gas CHHSLs, the model was used to back calculate the soil gas concentration of a chemical in soil needed to reach a specific target indoor air concentration. The target indoor air concentration (TIAC) is a concentration of a carcinogen where lifetime exposure will result in a one in a million excess cancer risk. For a non-carcinogen the TIAC is a concentration at a level where no adverse health effect is expected to occur from long-term exposure.

The sub-slab CHHSLs, which were not part of the OEHHA 2005 report, were calculated in a similar fashion to the soil gas CHHSLs, but the Johnson and Ettinger model was not used to calculate the attenuation factor. In this case, an attenuation factor of 0.05

was used. This attenuation factor is an empirically derived value suggested for use for sub-slab measurements by the Department of Toxic Substances Control.