Evaluation of Petroleum Products in Household Drinking Water for Impacts on Human Health

MIDDLESEX COUNTY,

VIRGINIA

Letter Health Consultation

May 18, 2026

Virginia Department of Health
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May 18, 2026

William Dale Berryman
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Dear Mr. Berryman,

Thank you for the opportunity to review water samples from a home on the Middlesex County Water Authority water supply where residents reported an odor of petroleum in the water. Based upon review of sampling results collected by the Virginia Department of Environmental Quality (DEQ), benzene and 1,2,4-trimethylbenzene exceeded their health-based comparison values but residents were not drinking the water for a long enough time for them to be at risk for health effects.

BACKGROUND

On April 10, 2025 the Office of Drinking Water contacted the Virginia Department of Health Public Health Toxicology Program requesting an assessment of petroleum and disinfection byproducts found in a drinking water sample. The samples were taken from a home that is served by the Middlesex Water Authority (MWA). Later additional samples were collected in June 2025 and results shared with the Toxicology Program. All sample results are in Table 1 on page 4. The MWA serves 700 customers, with 600 of them in Deltaville alone. The home sampled is at the end of a two-inch high density polyethylene (HDPE) water line bored for new construction. The water line is approximately three and half feet below the surface.

There are other customers connected to the same line, but they currently use private wells for potable water.

While the exact move-in date is unknown, residents likely moved in in April 2024 and first reported a chemical odor in the water on May 2, 2024. The odor appears to have initially been sporadic, because they did not contact the Middlesex Water Authority with an odor complaint again until August 8, 2024. They were advised to flush the taps, and this appears to have reduced the odor. Middlesex Water Authority installed a blowoff at the end of the main line so that it could be flushed without residents having to run their taps if odors reoccurred. On March 13, 2025, the residents' landlord contacted the Middlesex Water Authority to report their tenants had noticed reoccurred, intensified odor, and that they had switched to bottled water. At this point water sampling was carried out.

The source of the chemicals detected in the tap water was determined to be a nearby gas station that has been out of service for years. The gas station has several underground storage tanks previously used for storing gasoline. DEQ investigated the groundwater to determine the extent of contaminants. Flushing the water system supply line at the street began after the water contamination was discovered, but was not feasible as an ongoing measure to lower contaminant levels. The family temporarily took residence elsewhere while the investigation was completed and the home water supply was switched back to a pre-existing private well at their address.

DATA SCREENING

The Toxicology Program screens the results for each chemical using comparison values (CV). CVs are concentrations of chemicals in drinking water below which no adverse human health effects would be expected to occur. If the concentration of the chemical is higher than the corresponding CV, it does not mean that adverse health effects will occur; instead the chemical is evaluated further. CVs used to evaluate drinking water include:

- Maximum contaminant level (MCL) – the highest level of a contaminant that is allowed in drinking water. MCLs are set as close to maximum contaminant level goal (MCLG)[1] as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Environmental media evaluation guide (EMEG) – represent estimated contaminant concentrations below which humans exposed during a specific timeframe (acute,

[1] Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

intermediate, or chronic) are not expected to experience noncarcinogenic health effects.

- Reference dose media evaluation guide (RMEG) – represent the concentration in a specific medium (e.g., water, soil) at which daily human exposure for a chronic duration is unlikely to result in noncarcinogenic health effects.

The maximum concentrations for each chemical in water samples taken at the residents' water meter and within their home were compared to the CV. In the maximum concentrations measured in the home, benzene and 1,2,4-trimethylbenzene exceeded their CVs.

Chemicals present in the environment above their respective CVs can impact health only if people are exposed to them. The Toxicology Program determines if an exposure to environmental contamination occurred in the past, is occurring, or might occur in the future by identifying if a completed or potential exposure pathway exists. A completed exposure pathway consists of 5 elements:

1. A source of contamination
2. An environmental medium
3. A point of exposure
4. A route of exposure
5. And a receptor population

A *completed* pathway exists if all five elements are present. The Toxicology Program *eliminates* an exposure pathway if at least one of the five elements is missing and is very unlikely to be present at any time. A *potential* pathway exists if information on one of the five elements is missing or is insufficient but may be present currently or in the future.

A completed pathway exists for this address, since benzene and 1,2,4-trimethylbenzene were found in the water that residents were drinking.

Table 1. Combined sample results

Chemical	Kitchen	Bath-room	Water Heater	Meter	Max at Home	Down-stream	Up-stream	CV	CV Type
Benzene	**11.3**	<0.5	**7.4**	1.0	**11.3**	<0.5	<0.5	5	MCL
Ethylbenzene	--	17.2	99.6	56.8	99.6	<0.5	<0.5	N/A	N/A
Toluene	11.8	0.8	8.3	3.0	11.8	<0.5	<0.5	1000	MCL
Xylenes	--	60.3	--	198	198	<1.5	<1.5	7100	Acute EMEG Child
Chloroform	2.7	0.7	2.1	<0.5	2.7	<0.5	<0.5	80	MCL
Bromodichloromethane	1.1	1.2	1.2	1.0	1.2	0.9	1.0	80	MCL
Dibromochloromethane	1.8	2.1	2.0	1.9	2.1	1.9	2.0	80	MCL
Bromoform	0.9	1.5	1.1	1.6	1.6	1.6	1.7	80	MCL
Isopropylbenzene (cumene)	5.7	1.0	4.2	2.8	5.7	<0.5	<0.5	710	RMEG Child
1,4-Isopropyltoluene (p-cymene)	0.6	<0.5	0.6	<0.5	0.6	<0.5	<0.5	N/A	N/A
Naphthalene	19.2	2.6	16.8	11.9	19.2	<0.5	<0.5	140	RMEG Child
n-Propylbenzene	12.8	2.5	9.8	8.1	12.8	<0.5	<0.5	N/A	N/A
sec-Butylbenzene	0.7	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	N/A	N/A
1,2,4-Trimethylbenzene	**96.4**	16.4	**79.1**	63.8	**96.4**	<0.5	<0.5	71	RMEG Child
1,3,5-Trimethylbenzene	37.8	9.3	29.4	24.1	37.8	<0.5	<0.5	71	RMEG Child

Data provided by Virginia Department of Environmental Quality. All units in µg/L. **Bold font**: CV exceeded.

RISK EVALUATION

Benzene and 1,2,4-trimethylbenzene exceeded their CVs and were evaluated in a residential scenario. Residents likely moved into the home in April 2024 and switched to bottled water in early- or mid-March 2025. This would make the exposure timeframe less than one year. Since the exact dates the residents moved in and switched to bottled water are unknown, in an excess of caution we evaluated risks if residents were in the home for a full year. Risks were calculated over acute (14 days or less), intermediate (15 to 364 days), and chronic (more than 364 days) exposure scenarios and assuming either average water intake (central tendency exposure, or CTE) or highest likely water intake (reasonable maximum exposure, or RME). Full results can be seen in Attachment A.

In the chronic exposure scenario benzene cancer risks were about 1 in 10^6 (1 in 1,000,000) for children (birth to < 21 years) in the RME scenario, and lower for adults 21 years or older in the RME scenario and all age groups in the CTE scenario (see Table 2). These estimated risks present no concern for increased cancer risk.

Table 2. Cancer risk from chronic exposure (one year or more) to benzene

Exposure Group	CTE Cancer Risk	RME Cancer Risk
Child (birth to <21 years)	6.1×10^{-7}	1.1×10^{-6}
Adult (>21 year)	1.3×10^{-7}	3.2×10^{-7}

To determine if non-cancer health effects are possible, the dose people are exposed to is divided by the dose considered to not be a concern for health. This is called the hazard quotient. If the hazard quotient is greater than one more evaluation is needed to decide if non-cancer health risks are possible. In the chronic exposure scenario with CTE the hazard quotient exceeded one only for infants less than a year, while in the RME scenario hazard quotients were less than one for all age groups (see Table 3). In the intermediate and acute exposure scenarios, non-cancer health risks from benzene were only elevated in infants less than a year old in the RME scenario. All other age groups had hazard quotients less than one, meaning there is no concern for non-cancer health effects.

Table 3. Non-cancer risk from chronic exposure (one year or more) to benzene

Exposure Group	CTE Non-cancer Risk	RME Non-cancer Risk
Birth to < 1 year	2.9	5.3
Children 1 year to <21 years	<1	1.1 – 2.2
All adults	<1	1.5 – 1.6

For 1,2,4-trimethylbenzene, the only age group at risk with chronic exposure was infants less than a year in the RME scenario, with a hazard quotient greater than one for non-

cancer health risks (see Table 4). There were no elevated risks calculated in the intermediate or acute exposure time frames for any age group. Cancer risk was not calculated since 1,2,4-trimethylbenzene is not known to be carcinogenic.

Table 4. Non-cancer risk from chronic exposure (one year or more) to 1,2,4-trimethylbenzene

Exposure Group	CTE Non-cancer Risk	RME Non-cancer Risk
Birth to < 1 year	<1	1.4
Children 1 year to <21 years	<1	<1
All adults	<1	<1

This exposure scenario is conservative and residents' exposure timeframe may be shorter than one year. While the residents' move-in date is unknown, they probably were there for less than 12 months before switching to bottled water. The strength of the odor also apparently fluctuated, meaning contaminant concentrations may have been much lower for some time periods. If residents were exposed to contaminated water for less than one year, the potential for risk is even lower than estimated here. There was no increased risk for cancer with the conservative assumption of a full year of exposure. Non-cancer health effects are also unlikely since exposure for most people is consistent with the CTE scenario. In the CTE scenario with a full year of exposure non-cancer health risks were possible only for children under a year, but no infants live in the home. More information about the people in the home and their daily water use would help to more accurately evaluate potential for health risks, since there may be a potential for non-cancer health effects if residents consume much more water per day than typical use.

LIMITATIONS

Water samples were only taken when residents noticed the water smelled strongly like petroleum, so we do not know the concentration of contaminants throughout the time the residents lived in the home. However, concentrations of benzene and 1,2,4-trimethylbenzene only slightly exceeded their CVs, so concentrations of these chemicals were likely below the CV when residents could not detect an odor.

CONCLUSIONS

Concentrations of benzene and 1,2,4,-trimethylbenzene found in drinking water samples were unlikely to be a risk to health of the residents while they resided there. Residents lived in the home for only about a year. While we do not know the concentrations of these contaminants in the water over the full time period, residents only reported the odor sporadically and stopped drinking the water when it was tested. Even with the assumption

of a full year of exposure no health effects are expected. Young children under a year old are the most vulnerable group, but there were no infants in the home.

RECOMMENDATIONS

The residents switched back to an old private well and DEQ is working with the water authority on remediation. No recommendations are necessary.

Please let me know if you have any questions or additional information to consider. I can be reached at amy.hayes@vdh.virginia.gov or 804 864-8187.

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ATTACHMENT A. CANCER AND NON-CANCER HEALTH RISKS

Drinking Water Ingestion Chronic

Benzene

Table 1. Residential Site-specific exposure doses for chronic exposure to benzene in drinking water at 0.0113 mg/L along with non-cancer hazard quotients and cancer risk estimates*

Exposure Group	CTE Dose (mg/kg/day)	CTE Non-cancer Hazard Quotient	CTE Cancer Risk	RME Dose (mg/kg/day)	RME Non-cancer Hazard Quotient	RME Cancer Risk	Exposure Duration (yrs)
Birth to < 1 year	0.00086	2.9 †	-	0.0016	5.3 †	-	1
1 to < 2 years	0.00024	0.81	-	0.00065	2.2 †	-	0
2 to < 6 years	0.00022	0.73	-	0.00055	1.8 †	-	0
6 to < 11 years	0.00016	0.54	-	0.00045	1.5 †	-	0
11 to < 16 years	0.00011	0.37	-	0.00035	1.2 †	-	0
16 to < 21 years	0.00011	0.38	-	0.00035	1.2 †	-	0
Total Child	-	-	6.1E-7	-	-	1.1E-6 ‡	1
Adult	0.00019	0.62	1.3E-7	0.00046	1.5 †	3.2E-7	1
Pregnant Women	0.00018	0.60	-	0.00045	1.5 †	-	-
Breastfeeding Women	0.00023	0.77	-	0.00047	1.6 †	-	-

Source: Virginia Department of Environmental Quality
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher); yrs = years
* The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 0.055 $(mg/kg/day)^{-1}$.
† Indicates the hazard quotient is greater than 1, which the Public Health Toxicology Program evaluates further.
‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which the Public Health Toxicology Program evaluates further.

1,2,4-trimethylbenzene

Table 2. Residential Site-specific exposure doses for chronic exposure to 1,2,4-trimethylbenzene in drinking water at 0.0964 mg/L along with non-cancer hazard quotients*

Exposure Group	CTE Dose (mg/kg/day)	CTE Non-cancer Hazard Quotient	CTE Cancer Risk	RME Dose (mg/kg/day)	RME Non-cancer Hazard Quotient	RME Cancer Risk	Exposure Duration (yrs)
Birth to < 1 year	0.0074	0.74	-	0.014	1.4 †	-	1
1 to < 2 years	0.0021	0.21	-	0.0056	0.56	-	0
2 to < 6 years	0.0019	0.19	-	0.0047	0.47	-	0
6 to < 11 years	0.0014	0.14	-	0.0038	0.38	-	0
11 to < 16 years	0.00095	0.095	-	0.0030	0.30	-	0
16 to < 21 years	0.00097	0.097	-	0.0030	0.30	-	0
Total Child	-	-	-	-	-	-	1
Adult	0.0016	0.16	-	0.0039	0.39	-	1
Pregnant Women	0.0015	0.15	-	0.0039	0.39	-	-
Breastfeeding Women	0.0020	0.20	-	0.0040	0.40	-	-

Source: Virginia Department of Environmental Quality
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher); yrs = years
* The non-cancer hazard quotients were calculated using the chronic (lifetime) reference dose of 0.01 mg/kg/day.
† Indicates the hazard quotient is greater than 1, which the Public Health Toxicology Program evaluates further.

Drinking Water Ingestion Intermediate

Benzene

Table 3. Residential Site-specific exposure doses for intermediate exposure to benzene in drinking water at 0.0113 mg/L along with non-cancer hazard quotients*

Exposure Group	CTE Dose (mg/kg/day)	CTE Non-cancer Hazard Quotient	RME Dose (mg/kg/day)	RME Non-cancer Hazard Quotient
Birth to < 1 year	0.00086	0.96	0.0016	1.8 †
1 to < 2 years	0.00024	0.27	0.00065	0.72
2 to < 6 years	0.00022	0.24	0.00055	0.61
6 to < 11 years	0.00016	0.18	0.00045	0.50
11 to < 16 years	0.00011	0.12	0.00035	0.39
16 to < 21 years	0.00011	0.13	0.00035	0.39
Adult	0.00019	0.21	0.00046	0.51
Pregnant Women	0.00018	0.20	0.00045	0.50
Breastfeeding Women	0.00023	0.26	0.00047	0.53

Source: Virginia Department of Environmental Quality
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher)
* The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0009 mg/kg/day.
† Indicates the hazard quotient is greater than 1, which the Public Health Toxicology Program evaluates further.

1,2,4-trimethylbenzene

Table 4. Residential Site-specific exposure doses for intermediate exposure to 1,2,4-trimethylbenzene in drinking water at 0.0964 mg/L

Exposure Group	CTE Dose (mg/kg/day)	CTE Non-cancer Hazard Quotient	RME Dose (mg/kg/day)	RME Non-cancer Hazard Quotient
Birth to < 1 year	0.0074	-	0.014	-
1 to < 2 years	0.0021	-	0.0056	-
2 to < 6 years	0.0019	-	0.0047	-
6 to < 11 years	0.0014	-	0.0038	-
11 to < 16 years	0.00095	-	0.0030	-
16 to < 21 years	0.00097	-	0.0030	-
Adult	0.0016	-	0.0039	-
Pregnant Women	0.0015	-	0.0039	-
Breastfeeding Women	0.0020	-	0.0040	-

Source: Virginia Department of Environmental Quality
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher)

Drinking Water Ingestion Acute

Benzene

Table 5. Residential Site-specific exposure doses for acute exposure to benzene in drinking water at 0.0113 mg/L along with non-cancer hazard quotients*

Exposure Group	CTE Dose (mg/kg/day)	CTE Non-cancer Hazard Quotient	RME Dose (mg/kg/day)	RME Non-cancer Hazard Quotient
Birth to < 1 year	0.00086	0.96	0.0016	1.8 †
1 to < 2 years	0.00024	0.27	0.00065	0.72
2 to < 6 years	0.00022	0.24	0.00055	0.61
6 to < 11 years	0.00016	0.18	0.00045	0.50
11 to < 16 years	0.00011	0.12	0.00035	0.39
16 to < 21 years	0.00011	0.13	0.00035	0.39
Adult	0.00019	0.21	0.00046	0.51
Pregnant Women	0.00018	0.20	0.00045	0.50
Breastfeeding Women	0.00023	0.26	0.00047	0.53

Source: Virginia Department of Environmental Quality
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher)
* The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.0009 mg/kg/day.
† Indicates the hazard quotient is greater than 1, which the Public Health Toxicology Program evaluates further.

1,2,4-trimethylbenzene

Table 6. Residential Site-specific exposure doses for acute exposure to 1,2,4-trimethylbenzene in drinking water at 0.0964 mg/L

Exposure Group	CTE Dose (mg/kg/day)	CTE Non-cancer Hazard Quotient	RME Dose (mg/kg/day)	RME Non-cancer Hazard Quotient
Birth to < 1 year	0.0074	-	0.014	-
1 to < 2 years	0.0021	-	0.0056	-
2 to < 6 years	0.0019	-	0.0047	-
6 to < 11 years	0.0014	-	0.0038	-
11 to < 16 years	0.00095	-	0.0030	-
16 to < 21 years	0.00097	-	0.0030	-
Adult	0.0016	-	0.0039	-
Pregnant Women	0.0015	-	0.0039	-
Breastfeeding Women	0.0020	-	0.0040	-

Source: Virginia Department of Environmental Quality
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher)

Site-specific Input Parameters and Equations

Equations

Water Ingestion Exposure Dose Equation

$$D_{non\text{-}cancer} = (C \times IR \times EF_{non\text{-}cancer}) \div BW \quad \text{Equation 1}$$

$D_{non\text{-}cancer}$ = dose (mg/kg/day), C = contaminant concentration (mg/L), IR = intake rate (L/day), $EF_{non\text{-}cancer}$ = exposure factor (unitless), BW = body weight (kg)

Hazard Quotient

$$HQ = D_{non\text{-}cancer} \div HG \quad \text{Equation 2}$$

HQ = hazard quotient, $D_{non\text{-}cancer}$ = dose (mg/kg/day), HG = health guideline (e.g., oral MRL, RfD)

Cancer Risk Equations

$$CR = (D_{non\text{-}cancer} \times CSF) \times (ED \div LY) \text{ for each exposure group} \quad \text{Equation 3}$$

$$\text{ADAF-adjusted } CR = (D_{non\text{-}cancer} \times CSF) \times (ED \div LY) \times ADAF \text{ for each exposure group} \quad \text{Equation 4}$$

$$\text{Total } CR = \text{Sum of the CR for all exposure groups} \quad \text{Equation 5}$$

CR = cancer risk (unitless), D non-cancer = dose, CSF = oral cancer slope factor [(mg/kg/day)-1], EF (cancer) = exposure factor (cancer) calculated as follows: EF (non-cancer; unitless) x exposure group specific exposure duration (years) ÷ lifetime of 78 years, ADAF = age-dependent adjustment factor (unitless), ED = exposure duration (years), LY = lifetime years (78 years)

Site-specific Exposure Factors

Duration Category	Days per Week	Weeks per Year	Years	Exposure Group Specific $EF_{non\text{-}cancer}$	Exposure Group Specific* EF_{cancer}
Acute	-	-	-	1	-
Intermediate	7	-	-	1	-
Chronic	7	52.14	2	1	= $EF_{non\text{-}cancer}$ x ($ED_{age\text{-}specific\ (yrs)}$ ÷ 78 years)

Abbreviations: EF = exposure factor; NC = not calculated

* Cancer risk is averaged over a lifetime of exposure (78 years).

Site-specific Exposure Parameters

Exposure Group	Body Weight (kg)	Exposure Duration (years)	CTE Intake Rate (liters/day)	RME Intake Rate (liters/day)
Birth to < 1 year	7.8	1	0.595	1.106
1 to < 2 years	11.4	1	0.245	0.658
2 to < 6 years	17.4	0	0.337	0.852
6 to < 11 years	31.8	0	0.455	1.258
11 to < 16 years	56.8	0	0.562	1.761
16 to < 21 years	71.6	0	0.722	2.214
Total Child (all age groups)	-	2	-	-
Adult	80	2	1.313	3.229
Pregnant Women	73	-	1.158	2.935
Breastfeeding Women	73	-	1.495	3.061

Abbreviations: CTE = central tendency exposure (typical); kg = kilograms; RME = reasonable maximum exposure (higher)

Contaminant Information

Contaminant Name	Entered Concentration	EPC Type	Converted Concentration*
Benzene	11.3 µg/L	Maximum	0.0113 mg/L
1,2,4-trimethylbenzene	96.4 µg/L	Maximum	0.0964 mg/L

Abbreviations: µg/L = micrograms per liter; EPC = exposure point concentration; mg/L = milligram chemical per liter water
* Contaminant concentration converted to standard unit for calculating exposure.