



VILLAGE OF MOUNT HOREB

E. Main Street

Mount Horeb, WI 53572

Phone: (608) 437-6884 Fax: (608) 437-3190

Email: mhinfo@mounthorebwi.info Web: mounthorebwi.info

UTILITY COMMISSION AGENDA
Tuesday, April 8, 2025 at 7:00 PM

Municipal Building Board Room
138 E. Main Street
Mount Horeb, WI

- 1) Call to order
 - a. Roll Call
- 2) Public Comments – non-agenda items
- 3) Consent Agenda
 - a. Consideration of March 11, 2025 Meeting Minutes
- 4) Agenda Items
 - a. Consider Bank Account Information & Check Registers for March 2025
 - b. Discussion on Addition of Fluoride to Municipal Water
 - c. Discuss and Award North Road Boring Bids
 - d. Electric Department report
 - e. Water Superintendent report
 - f. Wastewater Superintendent report
- 5) Meeting adjournment.

UPON REASONABLE NOTICE, EFFORTS WILL BE MADE TO ACCOMMODATE THE NEEDS OF DISABLED INDIVIDUALS THROUGH APPROPRIATE AIDS AND SERVICES. FOR INFORMATION OR TO REQUEST THIS SERVICE, CONTACT ALYSSA GAFFNEY, CLERK, AT 138 E MAIN STREET, MOUNT HOREB, WI (608) 437-9404.



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UTILITY COMMISSION AGENDA
Tuesday, March 11, 2025 at 7:00 PM

DRAFT MEETING MINUTES

- 1) Call to order
The Utility Commission Committee meeting was called to order at 7:00 p.m. on the above date in the Board Room of the Municipal Building, 138 E. Main Street, Mount Horeb, WI.
 - a. Roll Call
Members present were Brett Halverson, Ed Glover, Mike McNall, Teri Vierima, and Jack Temby. Trustee Tim White and Citizen member Ken Scott were absent. Also present were Village Administrator Nic Owen, Electric Superintendent Jordan Schmitz, Wastewater Superintendent Mike Brace, Water Superintendent Brian Schult, and Finance Director/Treasurer Denise Schwenn.
- 2) Public Comments – non-agenda items
No public comments were brought forward.
- 3) Consent Agenda
A motion was made by Ed Glover, seconded by Mike McNall to approve the (consent agenda) January 14, 2025 meeting minutes. Motion carried.
 - a. Consideration of January 14, 2025 Meeting Minutes
- 4) Agenda Items
 - a. Consider Bank Account Information & Check Registers for January & February 2025
Motion by Vierima, seconded by Halverson to approve January 2025 and February 2025 bank account and check register information. Motion carried.
 - b. Electric Department Report-January & February 2025
Superintendent Schmitz reviewed the January and February 2025 Electric Utility Reports.
 - c. Water Superintendent Report-January & February 2025
Superintendent Schult reviewed the January and February 2025 Water Utility Reports.
 - d. Wastewater Superintendent Report-January & February 2025

Superintendent Brace reviewed the January and February 2025
Wastewater Utility Reports.

5) Meeting adjournment.

There being no further business before the Commission, McNall moved, Glover
seconded to adjourn the meeting at 7:29 p.m.

Minutes submitted by Denise Schwenn, Finance Director/Treasurer.

**MOUNT HOREB UTILITIES
FOR THE MONTH ENDING 03/31/25**

Checking Account Information

Transfers In/(Out):	
Sales Tax Payment	\$ (10,064.54)
Transfer from Village - sales tax	\$ 42.64
WPPI Monthly Payment	\$ (384,715.78)
Transfer to Village - Vouchers	\$ (160,643.65)
Transfer to Village - Payroll	\$ (153,289.41)
Transfer to Village - Garb/Recyc, Ins, PILOT, Interfund	\$ -
Transfer to Special Funds	\$ -
WDOR License fee assessment	\$ -
US Bank Rebate Q3	\$ -

Checking Account Balance*	
Electric Utility	716,021.90
Water Utility	999,646.79
Sewer Utility	1,673,366.77
Total Checking Account Balance	<u><u>3,389,035.47</u></u>

Special Funds Account Information
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Transfers In/Out:	
None	
Special Funds Account Balance*	
Electric Utility-General	(903,785.37)
Electric Utility-Special Redemption Fund	158,615.38
Electric Utility-Depreciation Reserve Fund	2,252,802.93
Electric Utility-Debt Service Reserve Fund	
Electric Utility-Construction Fund	1,742,815.80
Electric Utility Balance	<u><u>\$ 3,250,448.74</u></u>
Water Utility-General	328,121.57
Water Utility-Special Redemption Fund	455,806.70
Water Utility-Verizon Security Deposit	14,851.96
Water Utility-Depreciation Reserve Fund	429,818.91
Water Utility-Debt Service Reserve Fund	424,939.15
Water Utility Balance	<u><u>\$ 1,653,538.29</u></u>
Sewer Utility-General	(1,433,383.22)
Sewer Utility-Special Redemption Fund	1,124,799.55
Sewer Utility-Debt Service Reserve Fund	-
Sewer Utility-Environmental Impact Fee	51,447.96
Sewer Utility-Replacement Fund	1,483,040.56
Sewer Utility-Depreciation Reserve Fund	1,233,733.11
Sewer Utility Balance	<u><u>\$ 2,459,637.96</u></u>

Total Special Funds Investment Account \$ 7,363,624.99

W/T Bond payments	\$ -
Transfer to Village-PILOT/WWTP/Other	\$ -
Transfer from Village -	\$ -
Bond Issuance, Waterworks System Revenue Bond	\$ -

Report Criteria:

Report type: GL detail

Vendor.Vendor number = {<>} 2461

Check.Type = {<>} "Adjustment"

Invoice Detail.GL account (3 Characters) = "910","920","930"

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
135313									
03/25	03/05/2025	135313	5652	CENEX FLEETCARD-(WASTE	308143CL	930-582800-30	620.29	620.29	FLEET FUEL
Total 135313:								620.29	
135321									
03/25	03/05/2025	135321	33190	MOUNT HOREB TELEPHONE C	10630145	930-585100-30	234.81	234.81	PHONE/INTERNET
03/25	03/05/2025	135321	33190	MOUNT HOREB TELEPHONE C	10631656	910-556200-30	192.35	192.35	PHONE/INT
03/25	03/05/2025	135321	33190	MOUNT HOREB TELEPHONE C	10631656	920-592100-30	128.24	128.24	PHONE/INT
03/25	03/05/2025	135321	33190	MOUNT HOREB TELEPHONE C	10632858	910-592100-30	170.53	170.53	MUNI BLDG
03/25	03/05/2025	135321	33190	MOUNT HOREB TELEPHONE C	10632858	920-592100-30	127.90	127.90	MUNI BLDG
03/25	03/05/2025	135321	33190	MOUNT HOREB TELEPHONE C	10632858	930-585100-30	127.90	127.90	MUNI BLDG
Total 135321:								981.73	
135324									
03/25	03/05/2025	135324	96555	WISCONSIN HYDRANT REPAIR	25025	920-565100-30	650.00	650.00	REPLACED OPERATING NUTS
Total 135324:								650.00	
135325									
03/25	03/13/2025	135325	96443	ANIXTER INC	6306290-02	910-110710-000	359.16	359.16	PULLING LUBE
Total 135325:								359.16	
135326									
03/25	03/13/2025	135326	96093	B&B TRANSFORMER INC	29498	910-110712-000	37,824.00	37,824.00	TRANSFORMER
Total 135326:								37,824.00	
135328									
03/25	03/13/2025	135328	5651	CENEX FLEETCARD-(UTILITIES	308142CL	920-593300-30	274.61	274.61	FLEET FUEL
03/25	03/13/2025	135328	5651	CENEX FLEETCARD-(UTILITIES	308142CL	910-593300-30	851.49	851.49	FLEET FUEL

M = Manual Check, V = Void Check

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
Total 135328:								1,126.10	
135329									
03/25	03/13/2025	135329	6641	COMPUTER & NETWORKING S	7747	910-592300-20	344.40	344.40	TREND ANTI-VIRUS 2YR LIC RE
03/25	03/13/2025	135329	6641	COMPUTER & NETWORKING S	7747	920-592300-20	258.30	258.30	TREND ANTI-VIRUS 2YR LIC RE
03/25	03/13/2025	135329	6641	COMPUTER & NETWORKING S	7747	930-585200-20	258.30	258.30	TREND ANTI-VIRUS 2YR LIC RE
Total 135329:								861.00	
135332									
03/25	03/13/2025	135332	96636	DAVID STEINHAUER	2025-03	910-223200-00	71.72	71.72	FINAL CREDIT BALANCE REFU
Total 135332:								71.72	
135339									
03/25	03/13/2025	135339	96320	OPEN POINT LLC	1685	910-592300-20	1,450.00	1,450.00	SOFTWARE
Total 135339:								1,450.00	
135344									
03/25	03/13/2025	135344	58079	WISCONSIN RURAL WATER AS	S6942	920-593000-30	575.00	575.00	WISCONSIN RURAL WATER RE
Total 135344:								575.00	
135346									
03/25	03/20/2025	135346	55460	BAKER TILLY US, LLP	BT3086561	910-592300-20	9,821.41	9,821.41	2024 UTILITY AUDIT SVCS
03/25	03/20/2025	135346	55460	BAKER TILLY US, LLP	BT3086561	920-592300-20	7,366.07	7,366.07	2024 UTILITY AUDIT SVCS
03/25	03/20/2025	135346	55460	BAKER TILLY US, LLP	BT3086561	930-585200-20	7,366.07	7,366.07	2024 UTILITY AUDIT SVCS
Total 135346:								24,553.55	
135352									
03/25	03/20/2025	135352	96473	JOE KARLS	2025-03	910-225200-00	6,687.97	6,687.97	REFUND-METER ERROR
Total 135352:								6,687.97	
135358									
03/25	03/27/2025	135358	998	AMERICAN INDUSTRIAL MEDIC	25307VMH	930-585610-30	211.78	211.78	AUDIOGRAMS

M = Manual Check, V = Void Check

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
03/25	03/27/2025	135358	998	AMERICAN INDUSTRIAL MEDIC	25307VMH	910-593000-30	211.76	211.76	AUDIOGRAMS
03/25	03/27/2025	135358	998	AMERICAN INDUSTRIAL MEDIC	25307VMH	920-562300-30	105.88	105.88	AUDIOGRAMS
Total 135358:								529.42	
135359									
03/25	03/27/2025	135359	96443	ANIXTER INC	6306290-03	910-115410-000	219.45	219.45	STRANDWISE
03/25	03/27/2025	135359	96443	ANIXTER INC	6306290-03	910-557200-30	94.05	94.05	STRANDWISE
Total 135359:								313.50	
135360									
03/25	03/27/2025	135360	3172	CREATIVE SIGNWORKS	1668	910-593300-30	140.00	140.00	DECALS AND STRIPING TRUCK
Total 135360:								140.00	
135361									
03/25	03/27/2025	135361	1293	FEHR-GRAHAM & ASSOCIATES	129366	930-585430-30	806.64	806.64	SAFETY TRAINING
03/25	03/27/2025	135361	1293	FEHR-GRAHAM & ASSOCIATES	129366	910-592610-33	604.98	604.98	SAFETY TRAINING
03/25	03/27/2025	135361	1293	FEHR-GRAHAM & ASSOCIATES	129366	920-563200-30	403.32	403.32	SAFETY TRAINING
Total 135361:								1,814.94	
135362									
03/25	03/27/2025	135362	33130	MOUNT HOREB UTILITIES	2025-03 UTI	910-556200-30	216.70	216.70	ELECTRIC
03/25	03/27/2025	135362	33130	MOUNT HOREB UTILITIES	2025-03 UTI	920-562200-20	9,708.33	9,708.33	WATER
03/25	03/27/2025	135362	33130	MOUNT HOREB UTILITIES	2025-03 UTI	930-582100-20	11,151.43	11,151.43	SEWER
Total 135362:								21,076.46	
135364									
03/25	03/27/2025	135364	41010	PUBLIC SERVICE COMMISSION	2502-I-03930	910-110712-000	1,041.65	1,041.65	NORTH ROAD
03/25	03/27/2025	135364	41010	PUBLIC SERVICE COMMISSION	2502-I-03930	910-592300-20	279.56	279.56	WALLY RD
Total 135364:								1,321.21	
135365									
03/25	03/27/2025	135365	521	THE O'BRION AGENCY LLC	96237	910-592100-30	17.60	17.60	CASE OF PAPER
03/25	03/27/2025	135365	521	THE O'BRION AGENCY LLC	96237	920-592100-30	13.20	13.20	CASE OF PAPER

M = Manual Check, V = Void Check

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
03/25	03/27/2025	135365	521	THE O'BRION AGENCY LLC	96237	930-585100-30	13.20	13.20	CASE OF PAPER
Total 135365:								44.00	
901689									
03/25	03/05/2025	901689	3099	CLASSY CLEANERS	2482	920-593000-30	34.60	34.60	CLEANING
03/25	03/05/2025	901689	3099	CLASSY CLEANERS	2482	910-593000-30	138.40	138.40	CLEANING
03/25	03/05/2025	901689	3099	CLASSY CLEANERS	2483	910-593000-30	141.80	141.80	ELECTRIC
Total 901689:								314.80	
901693									
03/25	03/13/2025	901693	4045	BORDER STATES INDUSTRIES I	929916703	910-556200-30	1,130.82	1,130.82	SMU 20 FUSES
Total 901693:								1,130.82	
901694									
03/25	03/13/2025	901694	14485	FORSTER ELECTRICAL ENGIN	26101	910-592300-20	2,433.25	2,433.25	M25-22B
03/25	03/13/2025	901694	14485	FORSTER ELECTRICAL ENGIN	26102	910-592300-20	1,508.75	1,508.75	MILITARY RIDGE
03/25	03/13/2025	901694	14485	FORSTER ELECTRICAL ENGIN	26112	910-592300-20	8,226.25	8,226.25	M25-21F
03/25	03/13/2025	901694	14485	FORSTER ELECTRICAL ENGIN	26113	910-592300-20	211.25	211.25	M25-24B
03/25	03/13/2025	901694	14485	FORSTER ELECTRICAL ENGIN	26156	910-592300-20	307.56	307.56	TECH ASSISTANCE
Total 901694:								12,687.06	
901696									
03/25	03/13/2025	901696	841	LV LABORATORIES LLC	5089	930-582710-30	888.00	888.00	LAB TESTING
Total 901696:								888.00	
901697									
03/25	03/13/2025	901697	44670	RESCO	3062962	910-556200-30	716.15	716.15	STRAP HOIST
Total 901697:								716.15	
901702									
03/25	03/20/2025	901702	1137	INFOSEND INC	282600	910-592300-20	802.08	802.08	BILL PRINTING/MAILING
03/25	03/20/2025	901702	1137	INFOSEND INC	282600	920-592300-20	601.57	601.57	BILL PRINTING/MAILING
03/25	03/20/2025	901702	1137	INFOSEND INC	282600	930-585200-20	601.57	601.57	BILL PRINTING/MAILING

M = Manual Check, V = Void Check

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
Total 901702:								2,005.22	
901704									
03/25	03/20/2025	901704	484	STATEWIDE ENERGY EFFICIEN	2025-02	910-225300-00	3,052.83	3,052.83	ENERGY EFFICIENCY PROGRA
Total 901704:								3,052.83	
901707									
03/25	03/27/2025	901707	4045	BORDER STATES INDUSTRIES I	929982814	910-556200-30	24.97	24.97	SAW CHAIN
03/25	03/27/2025	901707	4045	BORDER STATES INDUSTRIES I	929992050	910-115400-000	10,785.30	10,785.30	ELBOWS AND URD WIRE
Total 901707:								10,810.27	
901710									
03/25	03/27/2025	901710	31623	ICS MEDICAL ANSWERING SER	2503000471	910-592100-30	120.58	120.58	TELEPHONE ANSWERING SVC
03/25	03/27/2025	901710	31623	ICS MEDICAL ANSWERING SER	2503000471	920-592100-30	90.43	90.43	TELEPHONE ANSWERING SVC
03/25	03/27/2025	901710	31623	ICS MEDICAL ANSWERING SER	2503000471	930-585100-30	90.43	90.43	TELEPHONE ANSWERING SVC
03/25	03/27/2025	901710	31623	ICS MEDICAL ANSWERING SER	2503000481	910-592100-30	64.48	64.48	TELEPHONE ANSWERING SVC
03/25	03/27/2025	901710	31623	ICS MEDICAL ANSWERING SER	2503000481	920-592100-30	48.36	48.36	TELEPHONE ANSWERING SVC
03/25	03/27/2025	901710	31623	ICS MEDICAL ANSWERING SER	2503000481	930-585100-30	48.36	48.36	TELEPHONE ANSWERING SVC
Total 901710:								462.64	
25031701									
03/25	03/17/2025	25031701	58071	WI DEPT OF REVENUE	2025-03-12	910-224100-00	10,064.54	10,064.54	SALES TAX PAYMENT-FEBRUA
Total 25031701:								10,064.54	
Grand Totals:								143,132.38	

Summary by General Ledger Account Number

GL Account	Debit	Credit	Proof
910-110710-000	359.16	.00	359.16
910-110712-000	38,865.65	.00	38,865.65

M = Manual Check, V = Void Check

GL Account	Debit	Credit	Proof
910-115400-000	10,785.30	.00	10,785.30
910-115410-000	219.45	.00	219.45
910-211100-000	.00	100,327.79-	100,327.79-
910-223200-000	71.72	.00	71.72
910-224100-000	10,064.54	.00	10,064.54
910-225200-000	6,687.97	.00	6,687.97
910-225300-000	3,052.83	.00	3,052.83
910-556200-300	2,280.99	.00	2,280.99
910-557200-300	94.05	.00	94.05
910-592100-300	373.19	.00	373.19
910-592300-200	25,384.51	.00	25,384.51
910-592610-335	604.98	.00	604.98
910-593000-300	491.96	.00	491.96
910-593300-300	991.49	.00	991.49
920-211100-000	.00	20,385.81-	20,385.81-
920-562200-200	9,708.33	.00	9,708.33
920-562300-300	105.88	.00	105.88
920-563200-300	403.32	.00	403.32
920-565100-300	650.00	.00	650.00
920-592100-300	408.13	.00	408.13
920-592300-200	8,225.94	.00	8,225.94
920-593000-300	609.60	.00	609.60
920-593300-300	274.61	.00	274.61
930-211100-000	.00	22,418.78-	22,418.78-
930-582100-200	11,151.43	.00	11,151.43
930-582710-300	888.00	.00	888.00
930-582800-300	620.29	.00	620.29
930-585100-300	514.70	.00	514.70
930-585200-200	8,225.94	.00	8,225.94
930-585430-300	806.64	.00	806.64
930-585610-300	211.78	.00	211.78
Grand Totals:	<u>143,132.38</u>	<u>143,132.38-</u>	<u>.00</u>

Dated: _____

Mayor: _____

City Council: _____

City Recorder: _____

Report Criteria:

Report type: GL detail

Vendor.Vendor number = {<>} 2461

Check.Type = {<>} "Adjustment"

Invoice Detail.GL account (3 Characters) = "910","920","930"

Report Criteria:

Only merchant vendors included

Report type: GL detail

Vendor.Vendor number = 2461

Check.Type = {<>} "Adjustment"

Invoice Detail.GL account (3 Characters) = "910","920","930"

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
25031901									
ADOBE SYSTEMS INCORPORATED									
03/25	03/19/2025	25031901	2461	U.S. BANK	6417-302900	930-583100-30	19.99	19.99	GIS SOFTWARE
Total ADOBE SYSTEMS INCORPORATED:								19.99	
AMARIL UNIFORM COMPANY									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-IV2741	910-593000-30	3,452.90	3,452.90	CLOTHING ALLOWANCE FOR 5
03/25	03/19/2025	25031901	2461	U.S. BANK	IV274403	910-593000-30	523.51	523.51	CLOTHING ALLOWANCE
Total AMARIL UNIFORM COMPANY:								3,976.41	
AMAZON.COM LLC									
03/25	03/19/2025	25031901	2461	U.S. BANK	6417-021725	930-582700-30	33.16	33.16	SNOWBLOWER REPAIR PARTS
Total AMAZON.COM LLC:								33.16	
AQUAFIX INC									
03/25	03/19/2025	25031901	2461	U.S. BANK	4019-016588	930-583100-30	2,339.01	2,339.01	LFT STATION DEGREASER
Total AQUAFIX INC:								2,339.01	
ARAMARK UNIFORM & CAREER APPAREL LLC									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614051	910-593000-30	17.12	17.12	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614051	920-593000-30	40.19	40.19	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614051	910-593000-30	17.12	17.12	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614051	920-593000-30	40.19	40.19	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614052	910-593000-30	17.12	17.12	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614052	920-593000-30	40.19	40.19	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614052	910-593000-30	17.12	17.12	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-614052	920-593000-30	40.19	40.19	UNIFORM ALLOWANCE
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-614051	930-585600-30	172.23	172.23	UNIFORM SERVICES

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
Total ARAMARK UNIFORM & CAREER APPAREL LLC:								401.47	
CHARTER COMMUNICATIONS HOLDING COMPANY									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-170918	910-592100-30	139.98	139.98	INTERNET
Total CHARTER COMMUNICATIONS HOLDING COMPANY:								139.98	
COMPLETE OFFICE OF WISCONSIN INC									
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-023337	920-592100-30	45.42	45.42	WATER JUGS
Total COMPLETE OFFICE OF WISCONSIN INC:								45.42	
CORE & MAIN LP									
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-W2590	920-564100-30	3,031.12	3,031.12	HYDRANT BUDDY TOOL FOR F
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-W4395	920-565300-30	449.83	449.83	1.5" OMNI WATER METER REGI
Total CORE & MAIN LP:								3,480.95	
ELECTRICAL TESTING LABORATORY LLC									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-42886	910-556200-30	543.79	543.79	HOSE AND BLANKET TESTING
Total ELECTRICAL TESTING LABORATORY LLC:								543.79	
FARM & FLEET OF MADISON INC									
03/25	03/19/2025	25031901	2461	U.S. BANK	6816-A35149	920-593000-30	134.89	134.89	CLOTHING ALLOWANCE SHAN
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-A35049	920-563200-30	52.00-	52.00-	RETURNED HEATER FOR CRE
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-A35151	920-563200-30	259.98	259.98	2 WALL HEATERS WELL #4 & #6
Total FARM & FLEET OF MADISON INC:								342.87	
HAMPTON INN EAU CLAIRE									
03/25	03/19/2025	25031901	2461	U.S. BANK	6218-829297	910-592610-33	475.00	475.00	BRYAN MOYER APP ROOM
03/25	03/19/2025	25031901	2461	U.S. BANK	9992-981664	910-556200-30	515.00	515.00	ROOM CHARGE FOR TRAINING
Total HAMPTON INN EAU CLAIRE:								990.00	
MADISON GAS & ELECTRIC									
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-840318	930-582100-20	1,154.88	1,154.88	WWTP
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-840318	920-564100-30	463.30	463.30	WATER

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-840318	910-556200-30	822.41	822.41	ELECTRIC
Total MADISON GAS & ELECTRIC:								2,440.59	
MARRIOTT MADISON WEST									
03/25	03/19/2025	25031901	2461	U.S. BANK	5459-71615	910-556200-30	458.96	458.96	ROOM CHARGE FOR TRAINING
Total MARRIOTT MADISON WEST:								458.96	
MOUNT HOREB AUTO SUPPLY INC									
03/25	03/19/2025	25031901	2461	U.S. BANK	7232-614174	930-583200-30	5.99	5.99	STARTING FLUID - GENERATOR
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-614830	920-593300-30	56.06	56.06	TRUCK #28 NEW WIPERS/WIND
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-614829	910-593300-30	22.36	22.36	HYDRAULIC FLUID TRUCK 22
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-614839	910-593300-30	16.77	16.77	GEAR LUBE TRUCK 22&23
Total MOUNT HOREB AUTO SUPPLY INC:								101.18	
O'REILLY AUTO PARTS									
03/25	03/19/2025	25031901	2461	U.S. BANK	7559-4406-3	930-582800-30	46.76	46.76	CRANE TRUCK OIL CHANGE
Total O'REILLY AUTO PARTS:								46.76	
POSTAL CONNECTION									
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-379552	920-563200-30	221.43	221.43	RETURN LOANER LAB TESTER
Total POSTAL CONNECTION:								221.43	
PREMIER COOPERATIVE									
03/25	03/19/2025	25031901	2461	U.S. BANK	1609-290670	910-556200-30	5.29	5.29	PRIMER
03/25	03/19/2025	25031901	2461	U.S. BANK	1609-290670	910-593300-30	20.97	20.97	DEICER
03/25	03/19/2025	25031901	2461	U.S. BANK	7232-022425	930-583400-30	76.25	76.25	CLEANING SUPPLIES
03/25	03/19/2025	25031901	2461	U.S. BANK	7559-021425	930-585600-30	36.96	36.96	CLEANING SUPPLIES
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-003011	910-593300-30	990.00	990.00	NEW TIRES SKIDSTEER
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-003011	920-593300-30	330.00	330.00	NEW TIRES SKIDSTEER
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-003014	920-593300-30	103.66	103.66	HYDRUALIC HOSE REPAIR
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-003014	910-593300-30	155.50	155.50	HYDRUALIC HOSE REPAIR
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-291653	910-556200-30	9.99	9.99	DEGREASER
03/25	03/19/2025	25031901	2461	U.S. BANK	9037-293843	910-556200-30	4.49	4.49	ALUMINUM CLAMPS

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
Total PREMIER COOPERATIVE:								1,733.11	
QUILL CORPORATION									
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-427334	930-585100-30	102.55	102.55	OFFICE SUPPLIES-WWTP
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-427355	930-585100-30	50.64	50.64	PAPER-WWTP
03/25	03/19/2025	25031901	2461	U.S. BANK	6917-428805	930-585100-30	20.99	20.99	PLANNER- M BRACE
Total QUILL CORPORATION:								174.18	
RINGCENTRAL INC									
03/25	03/19/2025	25031901	2461	U.S. BANK	4019-492309	930-585100-30	834.86	834.86	PHONE SERVICE
03/25	03/19/2025	25031901	2461	U.S. BANK	4019-494069	930-585100-30	417.43	417.43	PHONE SERVICE
Total RINGCENTRAL INC:								1,252.29	
SJ ELECTRIC SYSTEMS LLC									
03/25	03/19/2025	25031901	2461	U.S. BANK	4019-995582	930-583200-30	416.40	416.40	LILLEHAMMER LS SERVICE CA
03/25	03/19/2025	25031901	2461	U.S. BANK	4019-995582	930-583200-30	1,002.28	1,002.28	4TH ST LS SEAL FAIL REPAIR
Total SJ ELECTRIC SYSTEMS LLC:								1,418.68	
SLATE REOCK FR LLC									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-210239	910-593000-30	579.94	579.94	CLOTHING ALLOWANCE-CORE
Total SLATE REOCK FR LLC:								579.94	
UNITED STATES CELLULAR CORPORATION									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-335065	910-592100-30	24.75	24.75	USCELLULAR FEE
Total UNITED STATES CELLULAR CORPORATION:								24.75	
UTILITY SALES AND SERVICE INC									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-007817	910-593300-30	1,217.82	1,217.82	TRUCK 23 DIELECTRIC TESTIN
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-007817	910-593300-30	1,324.85	1,324.85	TRUCK 22 DIELECTRIC TESTIN
Total UTILITY SALES AND SERVICE INC:								2,542.67	
VIKING HARDWARE INC									
03/25	03/19/2025	25031901	2461	U.S. BANK	7232-022025	930-583400-30	28.99	28.99	BLDG 10 BALLAST/LIGHT

GL Period	Check Issue Date	Check Number	Vendor Number	Payee	Invoice Number	Invoice GL Account	Invoice Amount	Check Amount	Description
03/25	03/19/2025	25031901	2461	U.S. BANK	7232-022025	930-582800-30	31.96	31.96	WASHER/DEICER
03/25	03/19/2025	25031901	2461	U.S. BANK	7559-022025	930-585600-30	19.98	19.98	TRASH BAGS, SOAP
03/25	03/19/2025	25031901	2461	U.S. BANK	7559-022625	930-585600-30	17.94	17.94	GATES KEYS
Total VIKING HARDWARE INC:								98.87	
WI DEPT OF SAFETY & PROFESSIONAL SERVICE									
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-020035	910-593000-30	122.70	122.70	BOILER PERMIT
03/25	03/19/2025	25031901	2461	U.S. BANK	2527-020035	920-562300-30	30.68	30.68	BOILER PERMIT
Total WI DEPT OF SAFETY & PROFESSIONAL SERVICE:								153.38	
WISCONSIN STATE LABORATORY OF HYGIENE									
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-790747	920-564100-30	29.00	29.00	OVER DUE INVOICE FROM OCT
03/25	03/19/2025	25031901	2461	U.S. BANK	7887-802354	920-564100-30	31.00	31.00	MONTHLY FLUORIDE SAMPLE
Total WISCONSIN STATE LABORATORY OF HYGIENE:								60.00	
Total 25031901:								23,619.84	
Grand Totals:								23,619.84	

Summary by General Ledger Account Number

GL Account	Debit	Credit	Proof
910-211100-000	.00	11,495.46-	11,495.46-
910-556200-300	2,359.93	.00	2,359.93
910-592100-300	164.73	.00	164.73
910-592610-335	475.00	.00	475.00
910-593000-300	4,747.53	.00	4,747.53
910-593300-300	3,748.27	.00	3,748.27
920-211100-000	52.00	5,347.13-	5,295.13-
920-562300-300	30.68	.00	30.68
920-563200-300	481.41	52.00-	429.41
920-564100-300	3,554.42	.00	3,554.42
920-565300-300	449.83	.00	449.83
920-592100-300	45.42	.00	45.42

GL Account	Debit	Credit	Proof
920-593000-300	295.65	.00	295.65
920-593300-300	489.72	.00	489.72
930-211100-000	.00	6,829.25-	6,829.25-
930-582100-200	1,154.88	.00	1,154.88
930-582700-300	33.16	.00	33.16
930-582800-300	78.72	.00	78.72
930-583100-300	2,359.00	.00	2,359.00
930-583200-300	1,424.67	.00	1,424.67
930-583400-300	105.24	.00	105.24
930-585100-300	1,426.47	.00	1,426.47
930-585600-300	247.11	.00	247.11
Grand Totals:	<u>23,723.84</u>	<u>23,723.84-</u>	<u>.00</u>

Dated: _____

Mayor: _____

City Council: _____

City Recorder: _____

GL Account	Debit	Credit	Proof
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Report Criteria:

Only merchant vendors included

Report type: GL detail

Vendor.Vendor number = 2461

Check.Type = {<>} "Adjustment"

Invoice Detail.GL account (3 Characters) = "910","920","930"



AGENDA ITEM REPORT

MEETING DATE

April 8, 2025

PREPARED BY

Nicholas Owen, Administrator

AGENDA ITEM # 4.b

Discussion on Addition of Fluoride to Municipal Water

BACKGROUND

The City of Deforest recently made the decision to remove fluoride from their municipal water system. After that decision, two residents requested that the village take the same action. The Village of Mount Horeb reviewed this issue over ten years ago and decided to continue the use of fluoride. Our current fluoride level is at 0.70m/L or below and even if we stop adding fluoride to the system, our natural fluoride levels in our wells range from .07 to 0.14 residual. I'm including information, both for and against, adding fluoride to the water system in your packets. While there are studies showing potential negative side effects of fluoride use, the overall medical community, including Public Health Madison/Dane County, continues to recommend its use at a limited rate, which we have been using. The population most negatively affected by the removal of fluoride are youths living below the poverty rate who may not otherwise have access to fluoride treatments if it is removed from the water supply.

RECOMMENDATION

ATTACHMENTS

1. Emails Encouraging Continued Addition of Fluoride
2. WDA Letter of Support for Fluoridation 3.20.25
3. ASTDD for LOS for CWF Mt Horab WI - Village President Czyzewski
4. Community Water Fluoridation Mt Horeb
5. NIH Fluoride Fact Sheet for Health Professionals_6-28-2024
6. Request for removal of fluoride
7. Inga Iamandii et al 2023
8. Malin et al. 2024
9. summary of studies about Fluoride Information
10. Taylor et al. 2025

Emails Encouraging Continued Addition of Fluoride

From: Frederick Katz
Sent: Thursday, March 20, 2025 11:52:17 AM
To: Amanda Peterson
Subject: Re: Water Fluoridation in Mt. Horeb, WI

Dear Ms. Peterson:

Thank you for reaching out to the dental community at large. I have followed these types of discussions for many years, and the arguments are always the same. Either you believe that fluoride is a poison, and that topical applications are just as effective in reducing tooth decay, or you believe that water fluoridation is one of the greatest public health achievements in modern medicine. What has been missing from most of these debates, is the scientific fact that tooth decay has been reduced in children by 25%, not because of topical applications, which have been shown to have minimal effects, but because the fluoride molecule is taken up and incorporated into the developing appetite structure of the enamel. This occurs in utero and while the tooth (both primary and permanent) are FORMING. Once the tooth is formed, you cannot change its structure, which is totally different than what happens in long bones. Topical applications can have some effect, but nowhere near being able to achieve a 25% reduction in decay rate.

Anti-fluoride studies which are quoted to show effects on childhood IQ, were not done in the U.S.. Also, these studies showed no harmful effects at levels below 1.5 mg/L. Communal water supplies in the U.S., are set at 0.7mg/L.

I would ask you to consider the actual science of fluoridation when making decisions that will affect the youngest and most vulnerable in your community.

Feel free to share this letter of support.

Frederick L. Katz, B.S., D.D.S., M.S.D.

From: Ellen Kirschling
Sent: Thursday, March 20, 2025 11:27 AM
To: Nic Owen
Subject: Water Fluoridation Mt Horeb

Hello,

My name is Ellen Kirschling and I am the lead dentist at First Choice Dental in Verona. We see a fair number of patients from the Mount Horeb area at our practice so I felt it was my duty to reach out regarding concerns around fluoride. Since COVID, we have already seen a drastic decline in oral health and I fear removing fluoride will only add to this decline. If fluoride is removed, we dentists will still be there to treat our patients, but our focus is

always on the preventative way. Access to care is already an issue and removing fluoride will only worsen matters. The mouth is a gateway to the rest of the body and often reflects someone's overall health. Fluoride decreases cavities. Cavities are bacteria which can easily enter the bloodstream and cause inflammation and infection not only in the mouth, but around the heart or anywhere else in the body. Not only that, but a healthy smile contributes to quality of life. With Cavities comes stress, physical pain, financial strain (cost to fix it and missing work), and often decrease in self-image. I have attached some snippets below from an article the ADA (American Dental Association) put out.

The ADA in general is a great resource and I have attached a link here:

<https://www.ada.org/resources/community-initiatives/fluoride-in-water>

- " There is no question that fluoride compounds can be highly toxic, especially organic fluoride substances. It is equally clear the type of fluoride compound and concentration of the exposure are important in determining positive or negative health outcomes."
 - Meaning RAW Fluoride is toxic (as with many raw minerals) and the dose and type of fluoride is often what determines the toxicity
-
- "Most studies were conducted in countries outside the US and included fluoride exposure types, such as high fluoride coal burning, that are not presents stateside"
 - Meaning many of the studies done that show fluoride as toxic did not use the type of fluoride we use here in the states
-
- " The National Toxicology Program systemic review concluded with moderate confidence that excessive fluoride exposures - greater than 2 times the EPPA's community water fluoridation recommendation of 0.7 ppm fluoride - is associated with lower IQ in children"
 - Before this sentence the article was talking about how many studies on animals have been uninformative and many human studies have been inconclusive.
 - Meaning the toxic level is well above the recommended about
-
- "The reduction in caries equates to better health, more productivity from not missing school and work, and a marked decrease in the use of health care resources, to name a few. Fluoride remains the most effective therapeutic agent we have in our armamentarium to combat caries."
 - Meaning not only does fluoride decrease the risk of cavities, it also provides many other less measurable and more social/economical benefits (less money spent on dental care, not as long wait to get into dentist, children are less behaved when in pain from cavities, etc.)

- "The data and results of studies continue to show community water fluoridation is effective at caries prevention and is safe with no evidence of negative health effects" "We must continue to support research directed at answering questions related to the plausibility and mechanisms of fluoride's influence on neurodevelopment and health."
 - Meaning while the science supports fluoride now, we understand science changes. So, we should support the research needed to bring up more answers and explore all possibilities.

Thank you,

Ellen Kirschling, DMD
First Choice Dental

From: noreply@civicplus.com <noreply@civicplus.com>
Sent: Thursday, March 20, 2025 6:52 PM
To: Admin <Admin@mounthorebwi.info>
Subject: Online Form Submittal: Contact Us

Contact Us

Your Name	Bryan Wierwill, DDS
Your Email	docbry8146@aol.com
Subject	Fluoride in the water
Your Message	Fluoridation of the public water supply has been an "issue" that comes up every 30 years or so. Nothing has changed! Simply put, if you want to protect the children of Mt. Horeb from advance dental carious disease, the cheapest, safest, most efficient means is by adding fluoride to your water supply in the prescribed amounts. It really is THAT simple!

From: Beth Wagner
Sent: Thursday, March 20, 2025 10:19 AM
To: Nic Owen; Ryan Czyzewski
Subject: water fluoridation

Hello, as a dentist, parent and a resident of Mount Horeb I strongly recommend keeping fluoride in our water and the current (acceptable) levels. Removing fluoride from our water would directly affect the residents of the village with more tooth decay and increased expensive dental visits.

Thank you,
Elizabeth Wagner, D.M.D.

From: Strozier, Ronesha <RStrozier@publichealthmdc.com>
Sent: Friday, March 21, 2025 9:36 AM
To: Brian Schult <brian.schult@mounthorebwi.info>
Subject: Ronesha from Public Health Madison & Dane County: Information on Community Water Fluoridation

Hello Brian,

Below is some information to get you started.

Public Health Madison & Dane County is aligned with the state health department and national scientific consensus that community water fluoridation at the recommended level of 0.7 milligrams of fluoride per liter of water (mg/L) in the United States provides a benefit to the public's health. Community water fluoridation provides important and equitable access to oral health promotion regardless of age, race, ethnicity, education, income, insurance status, or access to dental care.

We understand that there is a lot of data and research to sort through. Below are some digital resources that may aid you in your discussion:

<https://ilikemyteeth.org/> I Like My Teeth from the American Academy of Pediatrics.

[Recording of the Public Health Madison & Dane County Presentation to the Village of DeForest Board of Trustees](#) (the link starts right at the beginning of the presentation). We gave a presentation at a DeForest Board of Trustees meeting. We also have a [fact sheet](#) with bullet points available.

[Centers for Disease Control – Fluoridation](#). This resource provides a general overview of community water fluoridation with current recommendations.

[American Dental Association ebook](#). This ebook answers frequently asked questions about Fluoride. (Link to download free copy at bottom of the webpage)

We will be following up next week with a document including common questions and answers to support your community discussion.

RONESHA STROZIER , MS, REHS (pronouns: she/her/hers)
Environmental Health Services Supervisor | [Public Health Madison & Dane County](#)

Executive Office
6737 West Washington Street
Suite 2360
West Allis, Wisconsin 53214
414.276.4520
414.276.8431 FAX



Legislative Office
5325 Wall Street,
Suite 2000
Madison, WI 53718
608.250.3442
608.282.7716 FAX

March 20, 2025

Dear Mt. Horeb Village President Czyzewski and Utility Commission,

Fluoridation of community water supplies is considered one of the most significant public health advances of the 20th century and one of the safest, most cost-effective ways to increase overall oral health. Since its introduction over 75 years ago, community water fluoridation has dramatically improved the dental health of tens of millions of Americans.

It has come to our attention that the Mt. Horeb Water Utility Commission will be discussing fluoridating of its local water system at its meeting on April 8th. I write – on behalf of 3,100 WDA dentists treating patients in the Mauston area and throughout the state – to ask you to consider the following:

- Fluoride is nature's cavity fighter, with small amounts present in all water sources such as lakes, rivers and wells. Community water fluoridation is simply the adjustment of fluoride already present in water to a very low level that helps prevent tooth decay.
- Under the Safe Drinking Water Act, the Environmental Protection Agency has established drinking water standards for a number of substances, including fluoride, to protect the public's health.
- The CDC reports that in 2020, 74% of the U.S. population on public water systems, or a total of 211.4 million people, had access to fluoridated water. The goal of the U.S. Department of Health and Human Services' Healthy People 2030 Objective is to reach 77%.
- The public health benefits of fluoridation are recognized in 75 years of studies from more than 125 national and international organizations, including the American and Canadian Dental Associations, US. Public Health Service, American Medical Association, American Cancer Society, American Academy of Pediatrics, the CDC and the World Health Organization. The best information with peer-reviewed studies is hosted by the American Academy of Pediatrics at <https://ilikemyteeth.org/>.
- The National Toxicology Program's (NTP) recent review of toxic fluoride levels does not provide any new or conclusive evidence that should compel any changes in current U.S. community water fluoridation practices because it did not find harm associated with the current optimally fluoridated water level of 0.7 parts fluoride per million. The ADA's official statement on the NTP Report can be found [here](#).
- The CDC also reports on average, communities with water fluoridation experience 25% fewer cavities, saving \$32 per person annually by avoiding dental treatment costs and leading to fewer missed work and school days.

On behalf of all the adults and children living in the Mt. Horeb area, the WDA urges local officials to maintain decay-preventing fluoride in the municipal water system.

Sincerely,

A handwritten signature in black ink, appearing to read "Tom Reid", with a stylized flourish at the end.

Dr. Tom Reid
WDA President





Association of State and Territorial Dental Directors

3858 Cashill Blvd, Reno, NV 89509 • Phone: 775-626-5008

Website: <http://www.astdd.org>

March 20, 2025

Dear Village President Czyzewski,

On behalf of the Association of State and Territorial Dental Directors (ASTDD), I am writing this letter to ask you for your support for continuing community water fluoridation in Mt. Horeb, WI. ASTDD's official policy is that we fully support and endorse community water fluoridation in all public water systems throughout the United States. Community water fluoridation has been demonstrated to be safe, cost-effective and beneficial through every stage of life and for all people, regardless of age, race, ethnicity or socioeconomic status.

Dental caries (tooth decay) is a chronic infectious disease that can begin in early infancy and that, by the time children reach adulthood, will affect over 92 percent of the U.S. adult population.¹ In addition, dental caries particularly affects low-income and socially-marginalized populations.^{2,3} Children from families with low incomes had nearly 12 times as many restricted-activity days (e.g., days of missed school) because of dental problems as did children from families with higher incomes.⁴

Scientific studies have confirmed the association between optimal levels of fluoride in water supplies, improved dental health and absence of any negative health impacts. As such, community water fluoridation has been the cornerstone of caries prevention in the United States.⁵ The CDC has recognized water fluoridation as one of ten great public health achievements of the twentieth century.⁶

In light of the above, I urge you to support the continuation of community water supplies in Mt. Horeb, WI. Support for community water fluoridation is a major achievement that will positively impact the health of your constituents.

Sincerely,

Dr. Russell Dunkel

Russ Dunkel, DDS, BS, BA, FACD, FICD, FPFA
President, ASTDD

Sources:

¹Dye BA, Tan S, Smith V, et al. Trends in oral health status: United States, 1988-1994 and 1999-2004. *Vital Health Stat 11*. April 2007;(248):1-92.

ASTDD is an affiliate of the Association of State and Territorial Health Officials

² Fisher-Owens SA, Gansky SA, Platt LJ, Weintraub JA, Soobader MJ, Bramlett MD, Newacheck PW. [Influences on children's oral health: a conceptual model. *Pediatrics*. 2007;120\(3\):e510-520.](#)

³ Petersen PE. [The World Oral Health Report 2003: continuous improvement of oral health in the 21st century – the approach of the WHO Global Oral Health Programme. *Community Dent Oral Epidemiol*. 2003;31\(s1\):3-24.](#)

⁴ Adams PF, Marano MA. 1995. *Current estimates from the National Health Interview Survey, 1994* (Vital and Health Statistics: Series 10, Data from the National Health Survey; no. 193). Hyattsville, MD: U.S. Department of Health and Human Services, National Center for Health Statistics.

⁵ Pollick HF. Water fluoridation and the environment: current perspective in the United States. *Int. J Occup Environ Health*.2004;10:343-350.

⁶Ten Great Public Health Achievements—United States, 1900-1999. *MMWR*. December 24, 1999;48(50):1141.

Community Water Fluoridation Data Snapshot

How can community water fluoridation help your community?

Mount Horeb, WI

1 Population served



2 Savings based on population

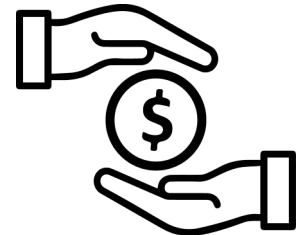
\$231,680/year



Individuals in communities that fluoridate water save an average of \$32 per person by avoiding dental care for cavities.

3 Poverty rate

2.7%



- Approximately **one out of 33** people in Mount Horeb are living in poverty.
- Children 2 to 5 years-old living in poverty are **three** times more likely to have untreated cavities. By ages 12 to 19, adolescents living in poverty are **twice** as likely to have untreated cavities in their permanent teeth.
- Low-income adults have **two to three** times more untreated cavities.
- Communities save **\$20** for every **\$1** invested in community water fluoridation.
- Nation-wide, nearly **\$6.5 billion** are saved per year by avoiding direct and indirect dental costs.



For more information on community water fluoridation, visit the Wisconsin Oral Health Program's website: www.dhs.wisconsin.gov/oral-health/community-water-fluoridation-fluoride.htm.



Fluoride

Fact Sheet for Health Professionals

Introduction

Fluoride, a mineral, is naturally present in many foods and available as a dietary supplement. Fluoride is the ionic form of the element fluorine, and it inhibits or reverses the initiation and progression of dental caries (tooth decay) and stimulates new bone formation [1].

Soil, water, plants, and foods contain trace amounts of fluoride. Most of the fluoride that people consume comes from fluoridated water, foods and beverages prepared with fluoridated water, and toothpaste and other dental products containing fluoride [2,3].

Approximately 80% or more of orally ingested fluoride is absorbed in the gastrointestinal tract [1]. In adults, about 50% of absorbed fluoride is retained in the body, with all but 1% stored in bones and teeth [1,3]. The other 50% is excreted in urine [1]. In young children, up to 80% of absorbed fluoride is retained because more is taken up by bones and teeth than in adults [1].

Individual fluoride status is not typically assessed, although fluoride concentrations can be measured in plasma, saliva, urine, bones, nails, hair, and teeth [4,5]. Criteria for adequate, high, or low levels of fluoride in the body have not been established.

Recommended Intakes

Intake recommendations for fluoride and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the National Academies of Sciences, Engineering, and Medicine [1]. DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and sex, include the following:

- **Recommended Dietary Allowance (RDA):** Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals; often used to plan nutritionally adequate diets for individuals
- **Adequate Intake (AI):** Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA
- **Estimated Average Requirement (EAR):** Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals
- **Tolerable Upper Intake Level (UL):** Maximum daily intake unlikely to cause adverse health effects

The FNB found the data insufficient to derive EARs for fluoride. Therefore, the board established AIs for all ages using estimated intakes shown to maximize reductions in the incidence of dental caries without unwanted side effects, such as dental fluorosis, a chronic condition resulting from the consumption of too much fluoride when teeth are developing [1]. Table 1 lists the current AIs for fluoride for healthy individuals.

Table 1: Daily Adequate Intakes (AIs) for Fluoride [1]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.01 mg	0.01 mg		
7–12 months	0.5 mg	0.5 mg		
1–3 years	0.7 mg	0.7 mg		
4–8 years	1 mg	1 mg		
9–13 years	2 mg	2 mg		
14–18 years	3 mg	3 mg	3 mg	3 mg
19+ years	4 mg	3 mg	3 mg	3 mg

Sources of Fluoride

Food

Brewed tea typically contains higher levels of fluoride than most foods, depending on the type of tea and its source, because tea plants take up fluoride from soil [1,3]. Fluoride levels can range from 0.3 to 6.5 mg/L (0.07 to 1.5 mg/cup) in brewed tea made with distilled water [3].

Fluoride concentrations in breast milk are so low that they cannot always be detected; when these levels can be measured, they range from less than 0.002 to 0.01 mg/L, even when mothers live in communities with fluoridated water [3]. Fluoride concentrations in cow’s milk are also very low, ranging from 0.007 to 0.086 mg/L [3]. Fluoride levels in infant formulas in the United States vary, depending on the type of formula and the fluoride content of the water used to prepare the formula [3]. The typical fluoride concentration is less than 0.2 mg/L in milk-based infant formula and 0.2 to 0.3 mg/L in soy-based infant formula (not including contributions from tap water used to prepare the formula).

Only trace amounts of fluoride are naturally present in most foods, and most foods not prepared with fluoridated water provide less than 0.05 mg/100 g [1,6].

A variety of types of foods and their fluoride levels per serving are listed in Table 2.

Table 2: Fluoride Content of Selected Foods [3,6,7]

Food	Milligrams per Serving
Tea, black, brewed, 1 cup	0.07 to 1.5*
Coffee, brewed, 1 cup	0.22*
Shrimp, canned, 3 ounces	0.17

Food	Milligrams per Serving
Bottled water with added fluoride, 1 cup	≤0.17
Raisins, ¼ cup	0.08
Oatmeal, cooked, ½ cup	0.08*
Grapefruit juice, ¾ cup	0.08
Potatoes, russet, baked, 1 medium	0.08
Rice, cooked, ½ cup	0.04*
Cottage cheese, ½ cup	0.04
Pork chop, baked, 3 ounces	0.03
Yogurt, plain, low-fat, 1 cup	0.03
Lamb chop, cooked, 3 ounces	0.03
Tortilla, flour, 1 tortilla, approx. 10" diameter	0.02
Corn, canned, ½ cup	0.02
Beef, cooked, 3 ounces	0.02
Tuna, light, canned in water, 3 ounces	0.02
Cheese, cheddar, 1½ ounces	0.01
Bread, white or whole wheat, 1 slice	0.01
Asparagus, cooked, 4 spears	0.01
Chicken, cooked, 3 ounces	0.01
Milk, fat-free or 1%, 1 cup	0.01
Apple, raw, with skin, 1 medium	0.01
Avocado, raw, ½ cup sliced	0.01
Macaroni, plain, cooked, ½ cup	0.00*
Tomato, raw, 1 medium	0.00
Banana, 1 medium	0.00
Egg, cooked, 1 large	0.00
Carrots, raw, 1 medium	0.00
Peanut butter, 1 tbsp	0.00

*Amounts of fluoride might vary by levels in the water used to prepare these foods and beverages.

Fluoridated drinking water

Since 1962, the U.S. Public Health Service has recommended the addition of fluoride to drinking (tap) water to reduce the risk and severity of dental caries, one of the most common chronic diseases in children [8]. Many countries around the world now adjust the fluoride concentration of community drinking water supplies to the level recommended for the prevention of dental caries [9].

Although the U.S. Public Health Service recommended fluoride concentrations of 0.7 in warmer climates (where children were expected to drink more water) to 1.2 mg/L in cooler climates to prevent dental caries in 1962, it amended its recommended level in 2015 to 0.7 mg/L to maintain the ability to prevent caries while minimizing the risk of dental fluorosis [8,10]. In 1986, guidelines from the U.S. Environmental Protection Agency (EPA) established a maximum allowable concentration of 4.0 mg/L fluoride in public drinking water systems to prevent adverse effects from fluoride exposure (such as bone disease) and a recommended maximum concentration of 2.0 mg/L to prevent dental fluorosis [3,11]. A review of this regulation is a currently a low priority for the EPA [12].

Fluoridated municipal drinking water—including water that people drink as well as foods and beverages prepared using municipal drinking water—accounts for about 60% of fluoride intakes in the United States [3,8]. In 2020, 62.9% of the U.S. population had access to a fluoridated community water system [13]. The fluoride additives used to fluoridate drinking water in the United States are fluorosilicic acid, sodium fluorosilicate, and sodium fluoride [14]. The Centers for Disease Control and Prevention has a [webpage \(https://nccd.cdc.gov/doh_mwf/Default/Default.aspx\)](https://nccd.cdc.gov/doh_mwf/Default/Default.aspx) that lists fluoride levels in tap water by county [15]. Because of differences in amounts of fluoride in groundwater, private water sources (including well water) have variable fluoride concentrations [11].

Fluoride is not typically added to bottled drinking waters. However, when fluoride is added, the U.S. Food and Drug Administration (FDA) stipulates that the total amount of fluoride (added plus naturally occurring) cannot exceed 0.7 mg/L [7]. Previously allowable levels ranged from 0.8 to 1.7 mg/L. FDA notes that this rule does not apply to bottled water without added fluoride that contains fluoride naturally from its source water. The amount of fluoride contained in bottled water is not required to be listed on the product label unless the label makes a claim about the product's fluoride content [16].

Dietary supplements

Only a few dietary supplements contain fluoride, usually in the form of sodium fluoride [17]. Most of these products are multivitamin/mineral supplements, multivitamins plus fluoride, or supplements containing trace minerals only. Some fluoride supplements, usually intended for children, are in the form of drops. The most common amount of fluoride in supplements is 0.25 mg, although a few products contain 0.5 or 1 mg per serving [17].

Dental products

Most toothpaste sold in the United States contains fluoride in the form of sodium fluoride or monofluorophosphate, most commonly at a level of 1,000 to 1,100 mg/L (about 1.3 mg in a quarter teaspoon, a typical amount of toothpaste used for one brushing) [3]. The amount of fluoride ingested from toothpaste depends on the amount used, the person's swallowing control, and how often the person uses toothpaste. **Estimated typical amounts of fluoride ingested daily from toothpaste are 0.1 mg to 0.25 mg for infants and children age 0 to 5 years, 0.2 to 0.3 mg for children age 6 to 12 years, and 0.1 mg for adults [3].** Fluoride in toothpaste, regardless of its form, is well absorbed [1].

Other dental products that provide fluoride include mouth rinses for home use, topical fluoride preparations applied in dentists' offices or through school-based programs, and dental devices (e.g., orthodontic bracket adhesives, glass-ionomer and some composite resin dental restorative materials, and some dental sealants and cavity liners) [3,18]. Gels used by dentists are typically applied one to four times a year and can lead to ingestions of 1.3 to 31.2 mg fluoride each time; varnishes are least likely to produce a high bolus of fluoride [3].

Medications

Some prescription medications contain fluoride, but not as the active ingredient. For example, voriconazole (VFEND or Vfend) is an oral antifungal medication used to treat several infectious conditions, including invasive aspergillosis, candidemia, and candidiasis [19]. Fluoride is a constituent of voriconazole and long-term use (e.g., for 4 months or more) of this medication can lead to high fluoride concentrations in serum and plasma [20-24]. The prescribing information for voriconazole advises discontinuation of voriconazole if skeletal fluorosis or periostitis (inflammation of the membrane surrounding and protecting the bones) develops [19].

Fluoride Intakes and Status

Most people in the United States consume adequate amounts of fluoride through foods containing naturally occurring fluoride, fluoridated tap water, and food products made with fluoridated tap water. According to the EPA, typical daily fluoride intakes in the United States from foods and beverages (including fluoridated drinking water) are 1.2 to 1.6 mg for infants and toddlers younger than 4 years, 2.0 to 2.2 mg for children age 4–11 years, 2.4 mg for those age 11–14 years, and 2.9 mg for adults [10].

Fluoride and Health

This section focuses on two conditions in which fluoride might play a role: dental caries and bone fractures.

Dental caries

Dental caries occurs when cariogenic bacteria in the mouth ferment foods and produce acids that dissolve tooth mineral [25]. Over time, this tooth decay can cause pain and tooth loss. Without treatment, dental caries can cause infections, impair growth and weight gain during childhood, affect school performance, impair quality of life, and possibly result in death [26-29]. Adequate fluoride intakes reduce the risk of dental caries in its initial stages by inhibiting demineralization and the activity of bacteria in dental plaque and by enhancing tooth remineralization [27].

Impact of water fluoridation on dental caries

Water fluoridation protects teeth in two main ways—by preventing the development of caries through ingestion of drinking water during the tooth-forming years and through direct contact of fluoride with

teeth throughout life [30,31].

A 2015 Cochrane Review included 20 prospective observational studies (most conducted before 1975) [9]. The results showed that children receiving fluoridated water had 35% fewer decayed, missing, and filled primary (baby) teeth, and 26% fewer decayed, missing, and filled permanent (adult) teeth than children receiving unfluoridated water. Fluoridation also increased the number of children with no decay in their baby teeth by 15% and the number of children with no decay in their permanent teeth by 14%. The authors concluded that water fluoridation is effective for reducing dental caries rates in both primary and permanent teeth in children. However, the reviewers were unable to assess the effectiveness of water fluoridation for preventing caries in adults because no evidence met the review's inclusion criteria (which required studies to include at least two groups, one receiving fluoridated water and one receiving unfluoridated water).

The Cochrane Review's findings were confirmed by a 2018 cross-sectional study on the associations between fluoridated community water and dental caries in the United States [32]. The authors analyzed data on 7,000 children age 2 to 8 years and 12,604 children and adolescents age 6 to 17 years who participated in the National Health and Nutrition Examination Study (NHANES) from 1999 to 2004 and 2011 to 2014, respectively. The results showed that living in a county in which 75% or more of the drinking water contained at least 0.7 mg/L fluoride was associated with a 30% reduction in the rate of caries in primary teeth and a 12% reduction in the rate of caries in permanent teeth.

Some evidence shows that the addition of fluoride to drinking water can also prevent dental caries in adults. An observational study included 3,779 individuals in Australia age 15 and older who participated in the Australian 2004–2006 National Survey of Adult Oral Health [33]. In adults exposed to fluoridated community water supplies for at least 14 years, rates of decayed, missing, or filled teeth were 11%–12% lower than in adults whose drinking water during this period had negligible amounts of fluoride. An earlier study in 876 Australian Defence Force members age 17–56 years found that the average rate of decayed, missing, and filled teeth was 24% lower in those with access to water containing 0.5 to 1 mg/L fluoride for at least half of their lifetime than in those exposed for less than 10% of their lifetime [34].

These findings show that fluoridated drinking water can prevent dental caries in children and adults.

Impact of fluoride dietary supplements on dental caries in children

Some studies have assessed the impact of fluoride supplements on caries development in children. For example, a 2011 Cochrane Review of 11 randomized or quasi-randomized studies in a total of 7,196 children (most living in communities lacking access to fluoridated drinking water) found that 0.25–1 mg/day supplemental fluoride for 24–55 months reduced rates of decayed, missing, and filled tooth surfaces by 24% [35]. The authors concluded that fluoride supplements were associated with a lower caries incidence rate in permanent teeth. A 2013 systematic review found an even greater preventive effect of fluoride supplements on the basis of one randomized and four nonrandomized clinical trials in children [28]. The results showed that 0.25–1 mg/day fluoride supplementation reduced caries incidence rates in primary teeth by 48%–72% in areas where water fluoridation levels

were lower than 0.6 mg/L. In two of these trials that monitored the children for 6–10 years, supplements were associated with a 33%–80% reduction in the incidence of caries at age 7–10 years.

The U.S. Preventive Services Task Force (USPSTF) and the American Dental Association have issued fluoride supplement recommendations for children whose water supply contains little or no fluoride [26]. These recommendations are summarized in Table 3.

Table 3: Expert Panel Recommendations for Fluoride Supplementation in Children

Source	Age Range	Recommendation
USPSTF [26]	6 months and older	• Fluoride supplement (dose not specified) for children whose water supply contains little or no fluoride*
American Dental Association [36]**	6 months to 3 years	• Fluoride supplement (0.25 mg/day) for children whose water supply contains less than 0.3 ppm (0.3 mg/L) fluoride
	3–6 years	• Fluoride supplement (0.5 mg/day) for children whose water supply contains less than 0.3 ppm (0.3 mg/L) fluoride • Fluoride supplement (0.25 mg/day) for children whose water supply contains 0.3 to 0.6 ppm (0.3 to 0.6 mg/L) fluoride
	6–16 years	• Fluoride supplement (1 mg/day) for children whose water supply contains less than 0.3 ppm (0.3 mg/L) fluoride • Fluoride supplement (0.5 mg/day) for children whose water supply contains 0.3 to 0.6 ppm (0.3 to 0.6 mg/L) fluoride

*No studies have addressed the dosage or duration of oral fluoride supplementation in this population.

**Recommended doses are based on poor-quality evidence.

Overall, the available evidence suggests that dietary supplements containing fluoride can reduce rates of dental caries in children who lack access to fluoridated drinking water. No studies have assessed the impact of fluoride supplements on caries development in adults.

Fluoride dietary supplements in pregnant women

Like other nutrients, fluoride is transferred from a pregnant woman to her fetus, so a few studies have evaluated the use of fluoride supplements by pregnant women to prevent dental caries in their children. However, the authors of a 2017 Cochrane Review found only one randomized controlled trial published in 1997 that met the review’s inclusion criteria [37]. This study assessed caries rates in 798 3-year-old children whose mothers had received 1 mg/day fluoride during the last 6 months of pregnancy [38]. The results showed no significant difference in the proportions of children who had decayed or filled primary tooth surfaces or who had caries. The authors of the Cochrane Review concluded that the 1997 study was of very low quality and that no evidence shows that fluoride supplementation in pregnant women prevents dental caries in their offspring.

Bone fractures

Because fluoride helps stimulate the formation of new bone, researchers have hypothesized that fluoride supplements might reduce bone fracture risk. However, research to date has provided only

limited evidence supporting this hypothesis [39-41].

The findings of observational studies on the impact of fluoride levels in water on bone mineral density (BMD) and fracture risk have been mixed. A study of 7,129 white women found no significant differences in bone mineral density or risk of hip, vertebral, wrist, or humerus fracture between those exposed and those not exposed to fluoridated water between 1950 and 1994 [40]. In contrast, in a study in 8,266 Chinese residents age 50 years or older, people with access to water fluoride levels of approximately 1 mg/L had a lower overall risk of fractures, but not of hip fractures, than those with access to water containing negligible fluoride levels [41].

Clinical trials have also had conflicting findings about the efficacy of fluoride dietary supplements to prevent bone fractures. For example, a meta-analysis of 25 randomized controlled trials in a total of 954 participants (four of the studies included people with osteoporosis) showed a significant reduction in vertebral and nonvertebral fracture risk with daily doses of up to 20 mg fluoride (in the form of monofluorophosphate or sodium fluoride), but not with higher doses [42]. A more recent randomized controlled trial found that 2.5, 5, or 10 mg/day fluoride for 1 year in 180 postmenopausal women did not change BMD at any site assessed [43].

Health Risks from Excessive Fluoride

Long-term ingestion of excess fluoride in infancy and childhood, when the teeth are being formed, can lead to dental fluorosis [44]. The characteristics of this chronic condition usually vary from almost imperceptible white lines or flecks to white or brown stains on teeth [2]. Severe dental fluorosis can lead to pitting in tooth enamel. The risk of dental fluorosis increases with fluoride intakes above recommended amounts [45]. Severe enamel fluorosis is rare and there is no indication that it is caused by recommended levels of community water fluoridation [3,31].

Analysis of 1999–2004 NHANES clinical exam data showed that 20.8% of people age 6 to 49 had mild or very mild dental fluorosis, 2.0% had moderate fluorosis, and less than 1% had severe fluorosis [44]. The prevalence of any dental fluorosis was highest, 40.6%, in adolescents age 12 to 15 and lowest, 8.7%, in those age 40 to 49.

Subsequent analyses of NHANES data from 2001–2002 and 2011–2012 found that rates of dental fluorosis (from very mild to severe) increased during this 10-year period [46,47]. However, a report from the Centers for Disease Control and Prevention concluded that the reported increase in dental fluorosis prevalence between NHANES 2001–2004 and 2011–2014 is not biologically plausible [48]. The authors suggested that there may have been a change over time in how the examiners evaluated the level of fluorosis [48,49].

Analyses of more recent NHANES 2015-2016 data showed that about two-thirds of children and adolescents age 6 years and older had some dental fluorosis, most of which was very mild or mild [48,50,51]. Research indicates that very mild or mild fluorosis does not negatively affect oral health-related quality of life [52,53]. Moreover, fluorosis severity tends to decline during adolescence and young adulthood [54,55]. Based on NHANES 2015-2016 data, only 1.4 to 1.8% of children and

adolescents age 6 years and older have moderate or severe fluorosis [48,50,51], and no evidence indicates that recommended levels of community water fluoridation lead to severe fluorosis [3,31].

High doses of fluoride (typically from rare accidents resulting in excessively high levels of fluoridation of water, unintentional ingestion of fluoride products intended for topical use in dentists' offices, or fluoride supplements inappropriately given to children) can result in nausea, vomiting, abdominal pain, diarrhea, periostitis, and even death in rare cases [3,19,56]. According to one estimate, the acute dose that could cause serious systemic toxicity for fluoride is 5 mg/kg (e.g., 375 mg for someone who weighs 75 kg [165 pounds]) [56]. This dose would be virtually impossible to achieve from water or toothpaste containing standard levels of added fluoride.

Chronic, excess intakes of fluoride are also associated with skeletal fluorosis [57]. Its effects can range from occasional joint pain or stiffness to osteoporosis, muscle wasting, and neurological defects [1,58]. However, skeletal fluorosis is extremely rare in the United States and no evidence indicates that it is caused by recommended levels of community water fluoridation [1,57].

One study found an association between higher maternal urinary fluoride concentration (based on one spot urine sample) during the third trimester of pregnancy and higher rates of neurobehavioral problems in the child at 3 years of age [59]. However, another study found no association between exposure to fluoridated water during early childhood and subsequent emotional or behavioral development and executive functioning [60]. Other evidence suggests that higher fluoride intakes during early development, including during gestation, might be associated with a lower IQ and other cognitive impairments (e.g., delays in cognitive development) in children [61-64]. However, many experts, including the authors of a National Academies of Sciences, Engineering, and Medicine review, consider this evidence to be weak and methodologically flawed [65-76]. A 2023 meta-analysis of 8 studies found that fluoride exposure at concentrations similar to that used in fluoridated community drinking water in the United States is not associated with lower IQ scores [77]. Reported associations between exposure to higher levels of fluoride and neurodevelopment warrant additional research [77,78].

The FNB has established ULs for fluoride from all sources for healthy individuals (Table 4) based on levels associated with dental and skeletal fluorosis [1].

Table 4: Daily Tolerable Upper Intake Levels for Fluoride [1]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.7 mg	0.7 mg		
7–12 months	0.9 mg	0.9 mg		
1–3 years	1.3 mg	1.3 mg		
4–8 years	2.2 mg	2.2 mg		
9–13 years	10 mg	10 mg		
14–18 years	10 mg	10 mg	10 mg	10 mg
19–51 years	10 mg	10 mg	10 mg	10 mg

Age	Male	Female	Pregnancy	Lactation
51+ years	10 mg	10 mg		

Interactions with Fluoride

Fluoride has no known, clinically relevant interactions with medications [79].

Fluoride and Healthful Diets

The federal government's 2020–2025 *Dietary Guidelines for Americans* notes that “Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. ... In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy).”

For more information about building a healthy dietary pattern, refer to the *Dietary Guidelines for Americans* (<https://www.dietaryguidelines.gov>) and the U.S. Department of Agriculture's *MyPlate*. (<https://www.choosemyplate.gov/>).

The *Dietary Guidelines for Americans* describes a healthy dietary pattern as one that

- Includes a variety of vegetables; fruits; grains (at least half whole grains); fat-free and low-fat milk, yogurt, and cheese; and oils.
- Includes a variety of protein foods such as lean meats; poultry; eggs; seafood; beans, peas, and lentils; nuts and seeds; and soy products.
- Limits foods and beverages higher in added sugars, saturated fat, and sodium.
- Limits alcoholic beverages.
- Stays within your daily calorie needs.

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Updated: June 26, 2024 [History of changes to this fact sheet](#)

March 31, 2025

Dear village commission,

I appreciate the time you are taking to consider the topic of removing fluoride from the Mt. Horeb village drinking water. I am encouraged to see all the communities that have removed fluoride from their water supply in Wisconsin, including DeForest, Amery, Mayville, Mellen, Oconto Falls, Rock Springs, Lake Delton, Oconto Falls, Saukville, Balsam Lake, St. Croix Falls, Chippewa Falls, Village of Orfordville, Hayward, Bloomer, Blue River, Shawano, Prairie du Chien, Montello, Shell Lake, Grantsburg, Milltown, Berlin, Luck, among others (2025 American Environmental Health Studies, JANA Life Sciences). In addition, the entire state of Utah has just recently banned water fluoridation. It is interesting to note that other nations including France, China, India, Japan, Germany, Belgium, the Netherlands, Denmark, Norway and Sweden prohibit fluoridation in the public water supply.

From my search of the literature, it appears that the fluoride used in the drinking water supply is not naturally-occurring fluoride; it is a byproduct created when making **phosphate fertilizer**. The three options for water fluoridation, which from my understanding are derived from the production of phosphate fertilizer are: sodium fluoride (NaF), sodium fluorosilicate (Na₂SiF₆), or fluorosilicic acid (H₂SiF₆). The above substances are very toxic in isolated form and have significant safety warnings. I am extremely concerned with these substances being added to our drinking water (even in its diluted form) and the long term effects of it being stored in our body.

There is no way to know precisely how much fluoride supplementation each person is consuming considering we are drinking it, cooking with it, bathing with it and making beverages with it. Many individuals are also using fluorinated toothpaste, floss and mouthwash. I am especially worried for young children and pregnant women as there is a recent meta-analysis and systematic review showing lower IQ in children with higher levels of fluoride in their water (Taylor et al., 2025). An additional study by Malin et al., 2024 found prenatal fluoride exposure associated with neurobehavioral problems in children. Additional studies show negative effects on thyroid function (Inga Iamandii et al., 2023).

Fluoride was originally added to the water supply system because it was thought that it helped prevent cavities. This recommendation was based on reports where fluoride was naturally-occurring in the drinking water (not added in its artificial form). If individuals are concerned about getting adequate fluoride for their teeth they still have access to fluoride toothpaste and mouth rinses. As an individual citizen, it is very difficult and expensive to remove fluoride from our own personal household drinking water once it has been added. Typically, it requires a household reverse osmosis water filtration system which unfortunately contributes to significant water waste, is very expensive and results in demineralization of the water.

I have included the studies I have referenced as well as additional resources. I appreciate the time you have taken to read this letter and consider my request.

Thank you,
Christie

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Review article

Does fluoride exposure affect thyroid function? A systematic review and dose-response meta-analysis



Inga Iamandii^a, Lisa De Pasquale^b, Maria Edvige Giannone^a, Federica Veneri^{c,d},
Luigi Generali^c, Ugo Consolo^c, Linda S. Birnbaum^e, Jacqueline Castenmiller^f,
Thorhallur I. Halldorsson^{g,h}, Tommaso Filippini^{a,i}, Marco Vinceti^{a,j,*}

^a Environmental, Genetic and Nutritional Epidemiology Research Center (CREAGEN), Section of Public Health, Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Modena, Italy

^b Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Modena, Italy

^c Department of Surgery, Medicine, Dentistry and Morphological Sciences with Transplant Surgery, Oncology and Regenerative Medicine Relevance (CHIMOMO), Unit of Dentistry & Oral-Maxillo-Facial Surgery, University of Modena and Reggio Emilia, Modena, Italy

^d PhD Program in Clinical and Experimental Medicine, Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Modena, Italy

^e Nicholas School of the Environment, Duke University, Durham, NC, USA

^f Office for Risk Assessment & Research, Netherlands Food and Consumer Product Safety Authority, Utrecht, the Netherlands

^g Department of Epidemiology Research, Centre for Fetal Programming, Copenhagen, Denmark

^h Faculty of Food Science and Nutrition, University of Iceland, Reykjavik, Iceland

ⁱ School of Public Health, University of California Berkeley, Berkeley, CA, USA

^j Department of Epidemiology, Boston University School of Public Health, Boston, MA, USA

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ABSTRACT

Introduction: Fluoride exposure may have various adverse health effects, including affecting thyroid function and disease risk, but the pattern of such relation is still uncertain.

Methods: We systematically searched human studies assessing the relation between fluoride exposure and thyroid function and disease. We compared the highest versus the lowest fluoride category across these studies, and we performed a one-stage dose-response meta-analysis for aggregated data to explore the shape of the association.

Results: Most retrieved studies (27 of which with a cross-sectional design) were conducted in Asia and in children, assessing fluoride exposure through its concentrations in drinking water, urine, serum, or dietary intake. Twenty-four studies reported data on thyroid function by measuring thyroid-related hormones in blood (mainly thyroid-stimulating-hormone - TSH), 9 reported data on thyroid disease, and 4 on thyroid volume. By comparing the highest versus the lowest fluoride categories, overall mean TSH difference was 1.05 μ IU/mL. Dose-response curve showed no change in TSH concentrations in the lowest water fluoride exposure range, while the hormone levels started to linearly increase around 2.5 mg/L, also depending on the risk of bias of the included studies. The association between biomarkers of fluoride exposure and TSH was also positive, with little evidence of a threshold. Evidence for an association between fluoride exposure and blood concentrations of thyroid hormones was less evident, though there was an indication of inverse association with triiodothyronine. For thyroid disease, the few available studies suggested a positive association with goiter and with hypothyroidism in both children and adults.

Conclusions: Overall, exposure to high-fluoride drinking water appears to non-linearly affect thyroid function and increase TSH release in children, starting above a threshold of exposure, and to increase the risk of some thyroid diseases.

* Corresponding author. Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Via Campi 287, 41125, Modena, Italy.

E-mail address: marco.vinceti@unimore.it (M. Vinceti).

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1. Introduction

Fluoride is the 13th most abundant element on Earth (Ghosh et al., 2013), naturally present in different amounts in certain foods, plants, and water (Singh et al., 2018; Ullah et al., 2017). Even though a small amount of exposure can occur from accidental ingestion of topical dental products, fluoridated water and fluoride-rich and enriched foods and beverages represent the main sources of fluoride intake (CDC, 2020; Lubojanski et al., 2023; Peckham and Awofeso, 2014). A too high fluoride exposure may adversely affect human health (Ahmad et al., 2022; Lubojanski et al., 2023; Shahab et al., 2017), with particular reference to dental and skeletal fluorosis (Fewtrell et al., 2007; Veneri et al., 2023a), and more recently growing body of evidence suggesting neurodevelopmental effects in children (Duan et al., 2018; Fiore et al., 2023; Veneri et al., 2023b). Moreover, high fluoride exposure has been associated with abnormal thyroid function, such as increased release and concentrations of thyroid-stimulating hormone (TSH), and decreased thyroxine (T4) and triiodothyronine (T3) levels (Andezhath et al., 2005; Wang et al., 2020). Despite a number of studies investigating the role of fluoride in thyroid toxicity, dose-response pooled estimates of the association between fluoride exposure and thyroid function and disease are still lacking (Chaitanya et al., 2018; Liu et al., 2014; Peckham et al., 2015). Therefore, we aimed at performing a systematic review and meta-analysis, also taking advantage from a statistical approach made recently available and suitable to characterize the shape of the relation between fluoride exposure and thyroid function, disease, and volume (Crippa et al., 2019).

2. Methods

2.1. Protocol and registration

We conducted this systematic review and meta-analysis according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021), after registering the study protocol in PROSPERO database (registration no. CRD42022321899).

2.2. Search strategy and study selection

The research question was designed according to the PECOS statement (Population, Exposure, Comparator, Outcomes, and Study design) (Morgan et al., 2018) as follows: "What is the effect of fluoride exposure on thyroid, according to a dose-response relation in humans?". Therefore, a study was considered eligible if it met the following inclusion criteria: (P) population of any age; (E) assessment of long-term fluoride exposure through drinking water or diet, and/or assessment of biomarkers of exposure (urinary or serum fluoride); (C) comparison of at least two categories of fluoride exposure; (O) biomarkers of thyroid function (e.g., TSH, T4, T3 hormones), thyroid disease risk (e.g., hypothyroidism, goiter) or thyroid volume as endpoints in (S) both nonexperimental (observational) or experimental (clinical trial) study design. Conversely, we excluded studies that did not present original data (e.g., review articles, editorials, comments, or guidelines) or were written in languages other than English. No restrictions were applied regarding the geographical location or publication date and, when more studies examined the same population, only the most complete one was included.

We performed a literature search through PubMed/MEDLINE, Web of Science, and Embase databases to retrieve studies published from inception up to November 15, 2023, by using the search terms "fluoride" and "thyroid". Details about the search strategies are reported in Supplementary Table S1. The studies identified were imported into the Rayyan web app for systematic reviews (Ouzzani et al., 2016) and their titles, abstracts and full-texts were reviewed independently by three authors (II, LDP and FV), in accordance with the eligibility criteria. Any

disagreements between these authors were resolved through the intervention of other two authors (MV and TF). Also, we searched backward and forward citations by manually checking the reference lists of these studies to retrieve additional literature of potential interest. To be further included in the meta-analysis, studies had to report effect/risk estimates according to exposure category, such as relative risk (RR), hazard ratio (HR), odds ratio (OR), mean difference (MD), or data allowing their calculation including the corresponding 95% confidence interval (95% CI), standard error (SE), standard deviation (SD), or interquartile range (IQR).

2.3. Data extraction

Data extraction from the eligible studies was independently performed by two authors (II and LDP) and verified by a third author (TF), using a standardized data collection form. We extracted the following information: (1) first author's name; (2) study characteristics (title, study design, country, publication year); (3) population characteristics (sex, age at baseline and sample size); (4) exposure characteristics (definition, assessment method, categories of exposure); (5) outcome characteristics (definition, assessment method, number of cases); (6) effect estimates (RRs, HRs, ORs, MDs) with their 95% CIs, SE, SD, or data to calculate them according to the Cochrane Handbook for Systematic Reviews of Interventions recommendations (Higgins et al., 2019), from the most-adjusted model; and (7) adjustment variables in the multi-variable analysis.

2.4. Risk of bias assessment

The risk of bias of the included studies was assessed independently by three authors (II, LDP, and MEG), using the most recent version of the Risk of Bias tool In Non-randomized Studies of Exposures "ROBINS-E" (Higgins et al., 2023). In case of disagreement between assessors, a decision was taken by involving a fourth author (MV). The tool was adapted to accommodate our specific research question and the characteristics of the studies selected by following seven bias domains (Supplementary Table 2): (1) bias due to confounding; (2) bias in selecting participants in the study; (3) bias in exposure measurement; (4) bias in departure from intended exposure; (5) bias due to missing data; (6) bias in outcome measurement; (7) bias in selection of reported results. For three domains (bias due to confounding, bias in selecting participants in the study, bias in outcome measurement), studies were judged to be at "Low", "Some concerns", "High", or "Very high" risk of bias. Studies were judged to be at "Low", "Some concerns", or "High" risk of bias for other three domains (bias in exposure measurement, bias due to missing data, bias in selection of reported results) and at "Low" or "Very high" risk of bias for bias in departure from intended exposure. Finally, the overall risk of bias of a study was considered "Low" if all domains were at "Low" risk of bias, "Some concerns" if at least one domain was found at "Some concerns" of bias, "High" if at least one domain was found at "High" risk of bias or four or more domains are at "Some concerns" of bias, and "Very high" if at least one domain was found at "Very high" risk of bias, or four or more domains are at "High" risk of bias.

2.5. Data analysis

We performed a meta-analysis by comparing the highest fluoride exposure category versus the lowest one and reporting the results in a forest-plot, using the restricted maximum likelihood random-effects model. When risk estimates for thyroid disease were unavailable, we extracted the number of cases and non-cases for each exposure category and then calculated the risk estimate alongside its 95% CI using the 'csi' routine of Stata software (v17.0, Stata Corp., College Station, TX, 2021). We stratified the analyses according to type of exposure indicator (e.g., water, urinary, serum fluoride, or daily fluoride intake), type of

endpoint (e.g., concentrations of thyroid-related hormones such as TSH, free T4, total T4, free T3, total T3, thyroid disease, and thyroid volume), and age categories (e.g., children, adults, children and adults), whenever data were available. We conducted sensitivity analyses excluding studies judged to be at “High” and/or “Very high” risk of bias. We also explored the shape of the association of fluoride exposure with thyroid-related hormone concentrations through a dose-response meta-analysis using a one-stage approach (Crippa et al., 2019; Orsini et al., 2022), in line with previous studies on other endpoints (Di Federico et al., 2023; Filippini et al., 2021). In particular, we used a restricted cubic spline with 3 knots at fixed cut-points (10th, 50th, and 90th percentiles) through the restricted maximum likelihood random-effects model. For this purpose, we extracted the mean/median fluoride levels or we computed the midpoint of each exposure category depending on data availability. If the highest and the lowest exposure categories were “open”, we calculated a value that was 20% higher or lower, respectively, than the closest cutpoint (Filippini et al., 2022; Vinceti et al., 2016). Finally, we assessed publication bias through visual inspection of symmetry in funnel plots and by performing Egger’s test when at least five studies were available for analysis (Egger et al., 1997), the heterogeneity of included studies using the I^2 statistics (Higgins et al., 2003), and by providing a graphical overlay of study-specific trends using predicted curves showing the influence of variation across studies (Murad et al., 2023; Orsini et al.,

2022). All analyses were performed with Stata software (v17.0, Stata Corp., College Station, TX, 2021).

3. Results

3.1. Study selection

Literature search and study selection process are described in the PRISMA flow-chart (Fig. 1). In the initial search, we identified 1232 articles, of which 187 were duplicate records. After screening for title and abstract, 975 studies were further removed because they were considered not relevant or they were written in languages other than English, leaving 70 studies for full-text assessment. Based on their evaluation, we additionally excluded 42 studies for the following reasons: (1) other publication type e.g., conference abstracts or reviews (n = 18); (2) outcome not of interest (n = 7); (3) full-text not available (n = 5, 3 of them published before 2000); (4) lack of details for exposure (n = 5); (5) correlation exposure-outcome not possible (n = 3); (6) duplicate population (n = 2); (7) unhealthy population (n = 1); (8) study design not eligible (n = 1). Eventually, 28 studies (Ahmed et al., 2022; Andezhath et al., 2005; Bachinsky et al., 1985; Barberio et al., 2017; Cui et al., 2020; Day and Powell-Jackson, 1972; Du et al., 2021; Eltom et al., 1984; Hall et al., 2023; Hong et al., 2008; Jooste et al., 1999; Karademir

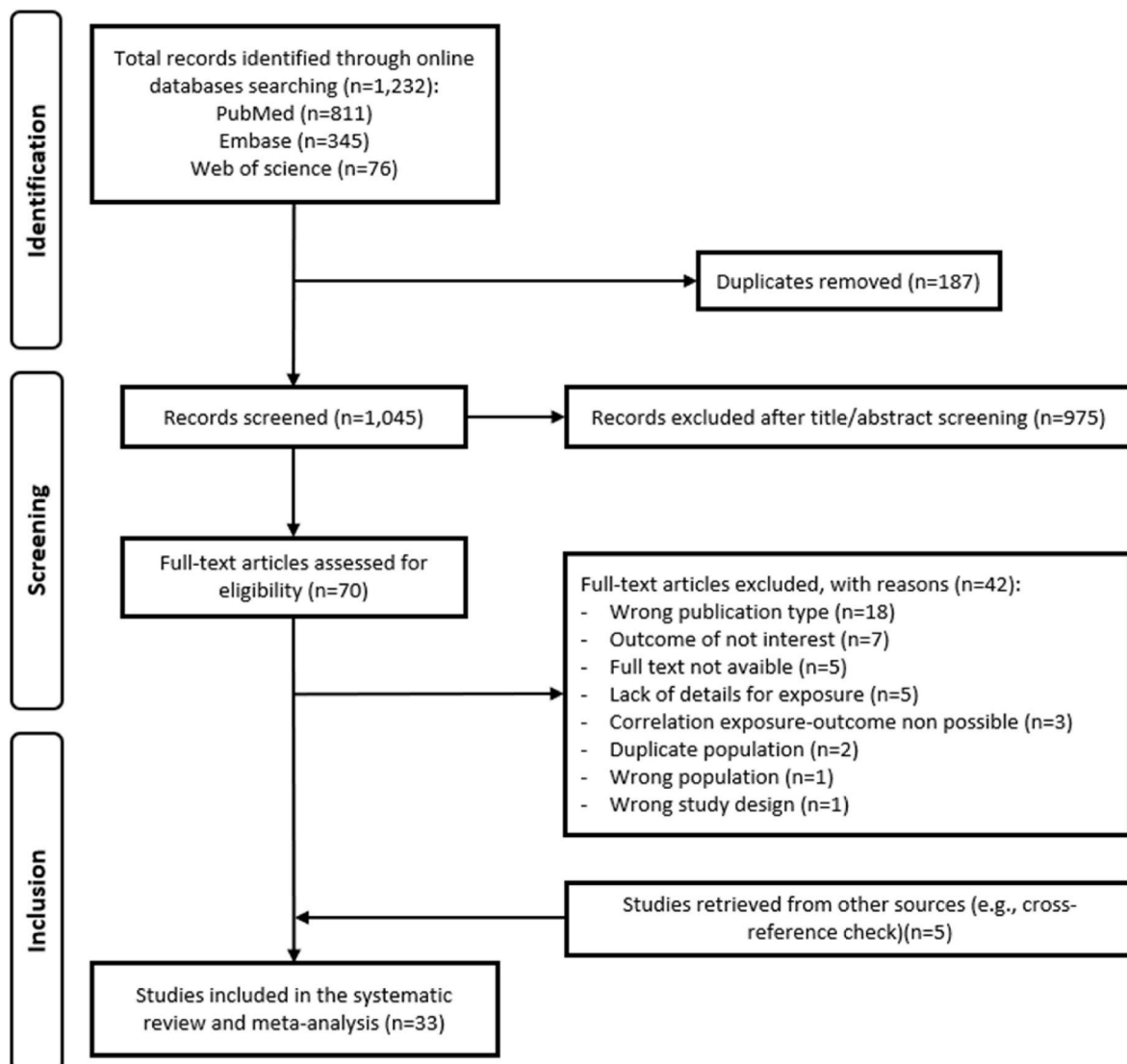


Fig. 1. PRISMA flow-chart of the inclusion process.

et al., 2011; Khandare et al., 2017, 2018; Kheradpisheh et al., 2018; Kumar et al., 2018; Kutluçan et al., 2013; Lathman and Grech, 1967; Michael et al., 1996; Peckham et al., 2015; Siddiqui, 1960; Szczuko et al., 2019; Wang et al., 2020, 2022; Xu et al., 2022; Yang et al., 2008; Yasmin et al., 2013; Zhang et al., 2015) were eligible for inclusion, to which we added 5 articles retrieved through citation chasing (Hosur et al., 2012; Shaik et al., 2019; Singh et al., 2014; Zulfiqar et al., 2019, 2020), resulting in 33 studies eventually included in our meta-analysis and suitable to assess the association between fluoride exposure and thyroid outcomes.

3.2. Characteristics of included studies

The key characteristics of the studies included in our meta-analysis are summarized in Table 1. Overall, these studies were published between 1960 and 2023, with 23 (70%) out of 33 being published from 2010 to 2023. The included studies had a pooled sample of nearly 45,000 participants (data missing for the large study by Peckham et al. (2015)), with an age between 6 and 79 years. Twenty-seven studies had a cross-sectional design, 5 case-control and 1 cohort study which was also the only report in pregnant women. Twenty-five studies were conducted in Asia (of which 10 in India and 8 in China), 3 studies in Europe, 3 in Africa, and 2 in Canada. All studies investigated different populations, with the partial exception of (Zulfiqar et al. 2019, 2020), which shared some participants. According to the available data, the exclusive evaluation of children was carried out in 22 studies (all but 1 from Asia), 7 studies involved both children and adults, and the remaining 4 studies included adult populations only. Almost half of the studies ($n = 14$) measured fluoride exposure through multiple modalities of assessment, such as drinking water, urinary, serum concentrations, or daily fluoride intake. Eleven studies were based solely on drinking water levels, 7 studies on urinary fluoride, and 1 on serum fluoride. Average fluoride concentrations in drinking water ($n = 25$) ranged from 0.08 to 25.10 mg/L (median: 0.80 and IQR: 2.04) and urinary fluoride ($n = 19$) ranged from 0.06 to 4.57 mg/L (median: 0.82 and IQR: 1.51). Lastly, the median \pm IQR value of fluoride found in serum ($n = 11$) was 0.065 ± 0.17 mg/L (range: 0.03–0.395). Most studies ($n = 24$) reported data on thyroid function by measuring thyroid-related hormones in the blood ($n = 24$ for TSH, $n = 22$ for T4, and $n = 21$ for T3), 9 studies reported data on thyroid disease diagnosis (7 on goiter, 1 on hypothyroidism, and 1 on unspecified thyroid disease, respectively) and 4 papers studied thyroid volume through ultrasound methods.

About half of the studies ($n = 16$) did not assess iodine status of study participants, 8 studies investigated subjects with rather homogeneous and adequate iodine status (4 assessing it at an ecologic level, 4 at the individual level by including only subjects with optimal iodine intake ($n = 3$) or not too high intake ($n = 1$), 1 of them also adjusting for urinary iodine in the multivariable analysis), 9 studies simply determined iodine exposure (8 in each of the fluoride exposure category, 1 independently from fluoride assessment). Among these 10 studies assessing iodine exposure, 1 study analyzed absorption of ^{131}I over 24 h by the thyroid, 2 studies reported iodine intake, 4 measured iodine exposure through drinking water concentration, and 3 by urinary concentration. In most of these studies, iodine and fluoride values increased ($n = 4$) or decreased ($n = 3$) in the same direction, while the remaining studies ($n = 3$) did not show a specific trend.

3.3. Risk of bias assessment

The results of the quality assessment study by Risk of Bias are reported in Supplementary Table S3. Overall, 5 studies were considered to be at “Very high” risk of bias, 10 at “High” risk of bias, 17 at “Some concerns”, and 1 at “Low” risk. Six studies were considered at “Low” risk of bias due to confounding, reporting adjustments for age, sex and iodine status; 22 were deemed to be at “Some concerns” of bias, since 9 of them

adjusted for two variables among age, sex, and iodine status, and 13 adjusted only for age; finally, 5 studies were considered at “Very high” risk of bias, since all of them did not report any adjustments. For one third of the studies the selection of eligible participants was not related to fluoride exposure, being at “Low” risk of bias for the related domain, while for 16 studies the selection of eligible participants was related to fluoride exposure, but they were recruited using the same inclusion-exclusion criteria, therefore, being considered at “Some concerns” for bias. Many studies ($n = 20$) were deemed at “Some concerns” of risk of bias in exposure classification, whereas 2 studies have not reported the exposure assessment method, making them at “High” risk of bias. All of the studies were considered at “Low risk” for bias in departure from intended exposure domain, because the exposure dose was always reported. Regarding bias due to missing data, 7 studies were considered at “High” risk, since the potential loss of subjects was not adequately documented and addressed, and 1 at “Some concerns”, because 19% of participants were excluded due to missing data. Moreover, 1 paper resulted at “High” risk of outcome measurement bias, because it had a self-reported assessment method of thyroid disease, and 6 studies were deemed at “Some concerns” of bias, since outcome assessment was based on clinical examination with no subsequent validation. Finally, most of the studies ($n = 20$) were considered at “Low” risk of selective reporting bias, and in 3 studies no protocol was available and a prior plan was not outlined in the methods, making them at “High” risk of bias.

3.4. Quantitative analysis

The study-specific and summary mean differences of TSH levels in children (age from 6 to 18 years), comparing the highest versus the lowest fluoride categories and according to the type of exposure assessment methodology, are displayed in Fig. 2. With regards to exposure to fluoride in drinking water ($n = 13$), the weighted mean TSH difference between the highest and the lowest exposure category was $1.17 \mu\text{IU/mL}$, with some inconsistencies across the different studies that were, however, characterized by high heterogeneity in the exposure categories compared and in their differences. Summary mean differences for urinary fluoride ($n = 15$) and serum fluoride ($n = 8$) in the highest exposure category, compared to the bottom one, were $0.97 \mu\text{IU/mL}$ and $1.46 \mu\text{IU/mL}$. Similar results were seen after we performed sensitivity analyses excluding the studies with “High” and “Very high” risk of bias (Supplementary Fig. S1), with 1.06, 0.52 and $1.09 \mu\text{IU/mL}$ mean TSH differences for water ($n = 8$), urinary ($n = 11$), and serum ($n = 5$) fluoride exposure, respectively. Furthermore, there was little evidence of publication bias regarding these outcomes, except for urinary fluoride exposure (Supplementary Fig. S2).

Analyses for thyroid hormones in children are shown in Supplementary Figs. S3–S5. The summary total T4 mean difference for water fluoride exposure category ($n = 6$) was $0.63 \mu\text{g/dL}$, while for urinary fluoride ($n = 7$) and serum fluoride ($n = 2$) the summary estimate was close to zero. Similarly, slight overall mean differences emerged for free T4, with values of -0.05 ng/dL for water fluoride ($n = 3$), -0.01 ng/dL for urinary fluoride ($n = 8$), and 0.04 ng/dL for serum fluoride ($n = 5$). Regarding analyses for total T3 levels, all summary mean differences between the highest and the lowest fluoride exposure category were almost null (-0.01 ng/mL for water fluoride in 6 studies, 0.00 ng/mL for urinary fluoride in 7 studies, and 0.02 ng/mL for serum fluoride in 2 studies), whereas for free T3 the difference was -0.10 pg/mL for water fluoride ($n = 7$), 0.20 pg/mL for urinary fluoride ($n = 8$), and 0.28 pg/mL for serum fluoride ($n = 5$). Study-specific and summary mean differences of thyroid volume and echobody index (total thyroid volume/body surface area) were possible only for urinary fluoride (Supplementary Fig. S4) due to limited data availability for other exposure metrics, and resulted in overall mean differences of -0.08 mL ($n = 4$) and 0.46 mL/m^2 ($n = 1$), respectively. Similar results can be seen excluding studies with “High” and “Very high” risk of bias (Supplementary Figs. S6–S8), for thyroid volume parameters and all hormones,

Table 1
Characteristics of the studies included in the review.

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
Ahmed et al. (2022)	Cross-sectional	Pakistan	242 subjects aged >12 years	Water [F] (mg/L): 0.30; 7.00	Fluoride Ion Selective Electrode (FISE)	Mean (SD) free T3 (µg/dL): 2.04 (0.49); 2.59 (0.56) Mean (SD) free T4 (nmol/L): 8.28 (2.16); 10.43 (2.34) Mean (SD) TSH (mIU/L): 1.94 (1.29); 2.59 (1.69)	Semiautomatic immunoassay analyzer (Immulite, 2000; Elecy, 2010)	No assessment	NR
Andezhath et al. (2005)	Cross-sectional	India	111 children aged 7–18 years	Water [F] (mg/L): 0.14–0.81; 0.14–0.73 Urinary [F] (mg/L): 0.09–1.32; 0.10–4.20 Serum [F] (mg/L): 0.02–0.14; 0.02–0.29	Fluoride ion specific electrode method (Ion 85 Analyzer)	Range free T3 (pg/mL): 1.80–2.80; 2.00–3.85 Range free T4 (ng/dL): 1.10–1.80; 0.97–1.50 Range TSH (µIU/mL): 1.20–2.10; 0.20–3.82	Immuno Chemiluminescence Microparticle Assay (ICMA)	No assessment	Age
Bachinsky et al. (1985)	Case-control	Ukraine	47 adults aged 19–59 years	Water [F] (µmol/L): 52; 122 Urinary [F] (µmol/L): 78; 124 Serum [F] (µmol/L): 11; 13	Fluoride selective electrode (EFU1)	Mean (SD) total T3: (nmol/L): 2.8 (0.3); 2 (0.2) Mean (SD) total T4 (nmol/L): 97 (8); 94 (6) Mean (SD) TSH (mIU/L): 2.4 (0.2); 4.3 (0.6)	TRIK-PEG test kit for T3, SPAC test kit for T4, and TSHKPR test kit for TSH	Determination of the intrathyroidal phase of iodine metabolism (absorption of ¹³¹ I by the thyroid) and fluoride levels in the study areas and population. Absorption of ¹³¹ I over 24 h by thyroid (%): 24; 33	NR
Barberio et al. (2017)	Cross-sectional	Canada	12,180 subjects aged 7–79 years	Urinary [F] (µmol/L): 33.55; 29.81	Fluoride ion selective electrode (Orion)	Thyroid condition diagnosis (cases/participants): 87/2530; 150/2671 Median (Q1-Q3) TSH (µIU/mL): 2.81 (2.21–3.81); 2.82 (2.01–3.82); 3.29 (2.30–4.48)	Self-reported diagnosis of a thyroid condition	No assessment	Age and sex
Cui et al. (2020)	Cross-sectional	China	498 children aged 7–12 years	Urinary [F] (mg/L): <1.6; 1.6–2.5; ≥2.5	Fluoride ion selective electrode method (Chinese standard WS/T 89–2015)	Median (Q1-Q3) TSH (µIU/mL): 2.81 (2.21–3.81); 2.82 (2.01–3.82); 3.29 (2.30–4.48)	Electrochemical luminescence method	Assessment of iodine levels was independent of assessment of fluoride levels.	Age
Day and Powell-Jackson (1972)	Cross-sectional	Nepal	648 subjects (500 children and 148 adults)	Water [F] (ppm): <0.1; 0.13; 0.13; 0.12; 0.19; 0.24; 0.22; 0.28; 0.21; 0.19; 0.36; 0.23; 0.23	Ion selective electrode	Goiter diagnosis (cases/participants): 2/38; 6/48; 4/31; 7/40; 10/50; 9/35; 10/36; 19/53; 40/85; 45/89; 23/43; 29/48; 36/52	Clinical examination according established guidelines	17 villages were visited and 736 people examined. 4 villages had relatively high water-iodine levels and were excluded. Our study is based upon data from the remaining 13 (648 people) which had a water-iodine concentration of 0.001 ppm or less.	Age, sex, and iodine status

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Table 1 (continued)

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
Du et al. (2021)	Cross-sectional	China	446 children (209 girls and 237 boys) aged 7–12 years	Urinary [F] (mg/L): 0.15–0.70; 0.71–1.35; 1.36–1.93; 1.94–5.18	Fluoride ion selective electrode method	β (95% CI) total T3 (nmol/L): ref; -0.08 (-0.21, 0.05); -0.15 (-0.29, -0.01); -0.21 (-0.37, -0.04) β (95% CI) total T4 (nmol/L): ref; 6.07 (-0.60, 12.73); 7.60 (0.41, 14.80); 9.75 (1.39, 18.11) β (95% CI) TSH (μ IU/mL): ref; 0.32 (-0.01, 0.65); -0.06 (-0.41, 0.30); -0.19 (-0.60, 0.23) β (95% CI) Tvol (cm^3): ref; 0.33 (0.13, 0.53); 0.56 (0.35, 0.77); 0.54 (0.30, 0.78)	Radiation immunoassay for thyroid hormones, and B-mode ultrasound method for thyroid volume	All children had sufficient iodine intake, therefore, children with urinary iodine <100 μ g/L (only 3 children) were excluded from our study. Adjustment for urinary iodine in the multivariable linear regressions analyses.	Age, sex, body mass index, maternal education, urinary creatinine, and urinary iodine
Eltom et al. (1984)	Cross-sectional	Sudan	13,682 subjects (mainly children)	Water [F] (mg/L): 0.30; 0.53	Radiometer electrode according to the Swedish standard (S.I.S. 0281 35)	Goiter diagnosis (cases/participants): 1039/7697; 2907/3353	Clinical examination according established guidelines	Determination of iodine and fluoride levels in the study areas and population. Iodine intake (μ g/day): 0.10; - (not assessed)	Age and sex
Hall et al. (2023)	Cohort (Maternal-Infant Research on Environmental Chemicals “MIREC” Study)	Canada	1508 pregnant women aged \geq 18 years, with <14 weeks gestation	Water [F] (mg/L): 0.41; 0.42; 0.48 Urinary [F] (mg/L): 0.59; 0.57; 0.62 F daily intake (mg/day): 0.65; 0.67; 0.78	Average water fluoride levels reported by the municipal WTPs (water treatment plant) for Water [F]; Ion selective electrode (modification of the hexamethyldisiloxane microdiffusion method) for Urinary [F]; Self-reported questionnaire for F intake	Mean (SD) free T4 (pg/mL): 13.50 (1.70); 13.10 (1.50); 14.00 (3.70) Mean (SD) total T4 (ng/mL): 105.80 (19.80); 107.10 (18.90); 109.30 (26.60) Mean (SD) TSH (μ IU/mL): 1.20 (0.55); 3.10 (0.66); 3.20 (2.80)	Gold standard equilibrium dialysis isotope dilution mass spectrometry (ED-ID-MS) for T4, and a commercial immunoassay for TSH	Determination of iodine and fluoride levels in the study areas and population. Iodine intake (μ g/day): 440.9; 458; 470	Age and sex
Hong et al. (2008)	Cross-sectional	China	205 children aged 8–14 years	Water [F] (mg/L): 0.48; 0.75; 2.85; 2.90; 2.94	Fluoride ion selective electrode method	Goiter diagnosis (cases/participants): 9/28; 1/32; 4/32; 1/85; 12/28	Clinical examination according to the International 2 grades classification system	Determination of iodine and fluoride levels in the study areas and population. Water iodine (μ g/L): 0.75; 150; 1150; - (not assessed); 0.91	Age
Hosur et al. (2012)	Case-control	India	75 children (27 boys and 38 girls) aged 7–18 years	Water [F] (ppm): <1.00; 0.50–4.00	Fluoride ion selective electrode method	Range free T3 (pg/mL): 2.72–3.79; 1.90–4.14 Range free T4 (ng/	Competitive chemiluminescent immunoassays for T3 and T4, and ultra-sensitive sandwich	No assessment	Age

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Table 1 (continued)

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
Jooste et al. (1999)	Cross-sectional	South Africa	671 children aged 6–15 years	Water [F] (ppm): 0.30; 0.50; 0.90; 1.10; 1.70; 2.60	NR	dL): 0.83–1.36; 0.83–1.25 Range TSH (μ IU/mL): 0.94–11.00; 0.43–5.91 Goiter diagnosis (cases/participants): 13/85; 22/127; 16/87; 5/95; 26/94; 53/183	chemiluminescent immunoassay method for TSH Clinical examination according established guidelines	Determination of iodine and fluoride levels in the study areas and population. Water iodine (μ mol/L): 0.83; >1.58; 1.00; -(not assessed); >1.58; 1.13	Age
Karademir et al. (2011)	Cross-sectional	Turkey	61 children aged 7–16 years	Urinary [F] (ppm): 0.20; 0.74; 0.90	Ion specific electrode method	Median (range) free T3 (pg/mL): 3.62 (2.69–4.41); 3.46 (2.74–4.14); 3.42 (2.69–4.41) Median (range) free T4 (ng/dL): 1.11 (0.85–1.64); 1.11 (0.63–1.53); 0.96 (0.85–1.11) Median (range) TSH (μ IU/mL): 1.81 (0.80–3.43); 2.14 (0.82–3.47); 1.56 (1.21–3.52)	Chemiluminescent micro-particle immunoassay (CMIA)	No assessment	Age
Khandare et al. (2017)	Case-control	India	824 children aged 8–15 years	Water [F] (mg/L): 1.13; 1.85 Urinary [F] (mg/L): 1.91; 3.28	Fluoride specific ion electrode (Orion 9609)	Mean (SD) total T3 (ng/mL): 0.68 (0.35); 0.63 (0.24) Mean (SD) total T4 (μ g/dL): 16.90 (1.60); 16.10 (2.90) Mean (SD) TSH (mIU/L): 3.40 (0.50); 2.90 (0.60)	DiaSorin kits for T3 and T4, and Immunoradiometric assay (IRMA) kit for TSH	No assessment	Age
Khandare et al. (2018)	Cross-sectional	India	1934 children (904 boys and 130 girls) aged 8–14 years	Water [F] (mg/L): 0.87; 2.53; 3.77; <1.00	Fluoride specific ion electrode (Orion 9609)	Mean (SD) total T3 (ng/mL): 2.17 (0.42); 1.57 (0.36); 1.34 (0.32); 1.46 (0.38) Mean (SD) total T4 (ng/mL): 112.69 (21.97); 116.03 (17.32); 132.8 (21.90); 84.40 (21.61) Mean (SD) TSH (μ IU/mL): 1.66 (0.49); 1.85 (0.46); 3.65 (1.04); 1.58 (0.44)	Radioimmunoassay (RIA) method	No assessment	Age

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Table 1 (continued)

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
Kheradpisheh et al. (2018)	Case-control	Iran	228 adults aged 20–60 years	Water [F] (mg/L): 0.00–0.29; 0.30–0.50	SPADANS method	Median (IQR) total T3 (ng/dL): 135.00 (18.40); 138.50 (21.60) Median (IQR) total T4 (µg/dL): 8.50 (1.20); 8.60 (1.20) Median (IQR) TSH (mIU/L): 2.20 (0.95); 2.80 (0.90)	Radioimmunoassay (RIA) method	No assessment	NR
Kumar et al. (2018)	Cross-sectional	India	400 children aged 8–15 years	Water [F] (ppm): 0.94–1.08; 1.50–5.00; 1.80–5.80 Urinary [F] (ppm): 0.22–1.07; 0.27–8.60; 0.60–7.64 Serum [F] (ppm): 0.03–0.10; 0.05–0.71; 0.05–0.71	Fluoride specific ion electrode	Range free T3 (pg/mL): 1.84–4.08; 1.20–4.21; 1.50–4.68 Range free T4 (ng/dL): 0.79–1.53; 0.96–1.82; 0.70–1.50 Range TSH (µIU/mL): 0.99–3.39; 1.34–8.31; 1.88–10.14	Immuno Chemiluminescence Microparticle Assay with Autoanalyzer	No assessment	Age
Kutlucan et al. (2013)	Cross-sectional	Turkey	559 children aged 10–15 years	Urinary [F] (mg/L): 0.22; 0.48	Fluoride selective electrode (Orion)	Mean (SD) Tvol (mL): 8.73 (2.75); 8.60 (3.11) Mean (SD) Ecobody index (mL/m ²): 6.48 (1.53); 6.94 (2.14)	Ultrasonography for thyroid volume	Determination of iodine and fluoride levels in the study areas and population. Urinary iodine (µg/L): 98.41; 93.12	Age and sex
Lathman and Grech (1967)	Cross-sectional	Tanzania	1243 children and adults	Water [F] (ppm): 18.60; 14.40; 25.10; 6.20; 2.60; 1.90	NR	Goiter diagnosis (cases/participants): 99/380; 10/30; 42/244; 26/121; 37/163; 126/305	Clinical examination	No assessment	NR
Michael et al. (1996)	Cross-sectional	India	500 subjects	Water [F] (ppm): 0.64; 2.70 Serum [F] (ppm): 0.04; 0.28	Ion selective electrode (Orion 701 A)	Mean (SE) total T3 (ng/mL): 1.50 (0.14); 1.53 (0.08) Mean (SE) total T4 (ng/mL): 9.16 (0.63); 14.77 (0.51) Mean (SE) TSH (µU/mL): 2.56 (0.36); 2.55 (0.37)	Radioimmunoassay (RIA) method for T3 and T4, and immunoradiometric assay method (IRMA) for TSH	No assessment	NR
Peckham et al. (2015)	Cross-sectional	UK	Subjects at 7935 General Practices in England (NR number of subject)	Water [F] (mg/L): 0.30–0.70; >0.70	[F] was provided by the Drinking Water Inspectorate (DWI)	ORs of upper tertile hypothyroidism prevalence: T1: reference; T2: 1.37 (1.12–1.68); T3: 1.62 (1.34–1.90)	Hypothyroidism prevalence obtained for all GP practices from the QOF data set	While iodine intake is a key determinant of thyroid status, the major source of iodine in the UK is from the diet and it is unlikely that there are	Proportion of women registered with the practice, proportion of patients over 40 years old registered

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Table 1 (continued)

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
Shaik et al. (2019)	Double-blinded observational trial (cross-sectional)	India	293 children aged 9–13 years	Water [F] (ppm): 0.22; 0.89; 1.44 Serum [F] (ppm): 0.03; 0.04; 0.05	Fluoride Ion Selective Electrode (F-ISE)	Mean (SD) ¹ total T3: 140.80 (23.69); 156.84 (84); 158.36 (22.13) Mean (SD) ¹ total T4: 8.79 (1.69); 9.29 (1.89); 9.54 (1.73) Mean (SD) TSH (mIU/L): 3.21 (1.78); 3.28 (1.30); 3.87 (1.48)	Competitive chemiluminescent immunoassay (CLIA) for T3 and T4 and ultra-sensitive sandwich CLIA for TSH	significant differences between people residing in fluoridated and non-fluoridated areas. The present study was carried out among children with normal nutritional status and optimal iodine intake.	with the practice, Index of Multiple Deprivation. Also, iodine status Age and iodine status
Siddiqui (1960)	Cross-sectional	India	2008 subjects (1495 children and 513 adults)	Water [F] (mg/L) 5.4; 6.1; 10.7	Thorium nitrate titration method	Goiter diagnosis (cases/participants): 21/1100; 24/813; 4/95	Clinical examination according established guidelines	Determination of iodine and fluoride levels in the study areas and population. Water iodine (µg/L): 175.30; 44.00; 14.40	Age and sex
Singh et al. (2014)	Cross-sectional	India	70 children aged 8–15 years	Water [F] (ppm): 1.60–5.10; 1.60–5.50; 0.98–1.00 Urinary [F] (ppm): 0.24–8.90; 0.40–7.79; 0.19–1.01 Serum [F] (ppm): 0.02–0.77; 0.03–0.75; 0.02–0.09	Fluoride ion specific electrode (Ion 85 Analyzer)	Range free T3 (pg/mL): 1.10–4.39; 1.20–4.57; 1.90–4.13 Range free T4 (ng/dL): 0.94–1.98; 0.80–1.70; 0.87–1.67 Range TSH (µIU/mL): 1.41–8.46; 1.92–10.99; 0.96–3.54	Immuno Chemiluminescence Microparticle Assay (ICMA)	No assessment	Age
Szczuko et al. (2019)	Case-control	Poland	40 women aged 18–38 years with PCOS (Polycystic ovary syndrome)	Serum [F] (ppm): 0.19; 0.25	Fluoride ion selective electrode (Orion 9409 BN)	Mean (SD) TSH (mIU/mL): 1.68 (0.81); 2.18 (0.60)	Electro-chemiluminescence immunoassay (ECLIA)	No assessment	Age and sex
Wang et al. (2020)	Cross-sectional	China	571 children aged 7–13 years	Water [F] (mg/L): 0.56; 0.85; 1.45; 2.28 Urinary [F] (mg/L): 0.12; 0.28; 1.35; 2.74	Fluoride ion selective electrode (ion analyzer EA940)	Water [F]: β (95% CI) total T3 (ng/mL): ref; –0.03 (–0.08, 0.02); 0.03 (–0.01, 0.07); 0.02 (–0.03, 0.06) β (95% CI) free T3 (pg/mL): ref; –0.02 (–0.11, 0.07); 0.09 (0.02, 0.16); 0.05 (–0.03, 0.12) β (95% CI) total T4 (µg/dL): ref; –0.38	Chemiluminescent microparticle immunoassay (ARCHITECT i4000SR)	None of the study sites was delimited into endemic areas of iodine deficiency disorders which were determined by thyroid status examination and the median urinary iodine concentration in the population.	Age, sex, body mass index, paternal education, maternal education, household income, and low birth weight. Also, iodine status

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Table 1 (continued)

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
						(-0.69, -0.07); -0.44 (-0.69, -0.19); -0.27 (-0.52, -0.02) β (95% CI) free T4 (ng/dL): ref; -0.03 (-0.06, 0.003); -0.03 (-0.05, -0.001); -0.04 (-0.06, -0.01) β (95% CI) TSH (μIU/mL): ref; -0.15 (0.52, 0.21); 0.24 (-0.01, 0.52); 0.31 (0.01, 0.60) Urinary [F]: β (95% CI) total T3 (ng/mL): ref; 0.04 (-0.001, 0.09); 0.08 (0.04, 0.13); 0.04 (-0.01, 0.08) β (95% CI) free T3 (pg/mL): ref; 0.05 (-0.03, 0.12); 0.14 (0.06, 0.21); 0.08 (0.001, 0.16) β (95% CI) total T4 (μg/dL): ref; 0.04 (-0.23, 0.31); -0.25 (-0.51, 0.02); -0.21 (-0.48, 0.06) β (95% CI) free T4 (ng/dL): ref; -0.002 (-0.03, 0.03); -0.03 (-0.06, 0.001); -0.02 (-0.05, 0.005) β (95% CI) TSH (μIU/mL): ref; 0.02 (-0.29, 0.33); 0.23 (-0.08, 0.54); 0.36 (0.05, 0.67)			
Wang et al. (2022)	Cross-sectional	China	413 children (198 boys and 215 girls) aged 7-12 years	Urinary [F] (mg/L): 0.78; 1.46	Fluoride ion selective electrode method	Median (Q1-Q3) free T3 (pmol/L): 6.49 (6.08, 6.93); 6.59 (6.23, 7.15) Median (Q1-Q3) free T4 (pmol/L): 18.39 (16.94, 19.77); 17.30 (16.07, 18.60) Median (Q1-Q3)	Electrochemiluminescence method for thyroid hormones, and B-mode ultrasound for thyroid volume (Tvol)	According to the data of children's urinary iodine published annually by the Tianjin Health Commission, Beichen and Xiqing are not iodine malnutrition areas. Determination of iodine and fluoride levels in the study areas and	Age, sex, and iodine status

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Table 1 (continued)

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
						TSH ($\mu\text{IU/mL}$): 2.90 (2.24, 3.82); 2.75 (2.13, 4.21) Median (Q1-Q3) Tvol (ml): 3.63 (2.66, 4.44); 2.52 (2.02, 3.27)		population. Urinary iodine ($\mu\text{g/L}$): 167.00; 159.20	
Xu et al. (2022)	Cross-sectional	China	424 children (226 boys and 198 girls) aged 7–12 years	Urinary [F] (mg/L): 0.80; 1.51	Fluoride ion selective electrode method	Mean (SD) total T3 (nmol/L): 2.58 (0.45); 2.59 (0.59) Mean (SD) total T4 (nmol/L): 135.29 (25.42); 134.13 (26.20) Median (IQR) TSH: ($\mu\text{IU/L}$): 1.53 (1.18, 2.05); 1.58 (1.28, 2.03) Mean (SD) Tvol (cm ³): 2.78 (1.11); 3.16 (1.16)	Radiation immunoassay (RIA) method for thyroid hormones, and B-mode ultrasound for thyroid volume (Tvol)	Almost all children had appropriate iodine intake, which may be due to the diversity of food and the implementation of iodized salt policy. Determination of iodine and fluoride levels in the study areas and population. Urinary iodine ($\mu\text{g/L}$): 351.70; 346.70	Age, sex, and iodine status
Yang et al. (2008)	Cross-sectional	China	1518 children aged 8–14 years	Water [F] (mg/L): 0.50; 2.97 Urinary [F] (mg/L): 0.82; 2.08	Fluoride ion selective electrode method	Mean (SD) total T3 ($\mu\text{g/dL}$): 0.74 (0.43); 0.76 (0.36) Mean (SD) total T4 (ng/dL): 128.46 (38.12); 147.83 (88.31) Mean (SD) TSH ($\mu\text{IU/mL}$): 0.82 (0.51); 3.37 (2.16) Goiter diagnosis (cases/participants): 2/416; 42/1102	Radioimmunoassay (RIA) method for thyroid hormones and clinical examination according to national standards for endemic goiter control	Determination of iodine and fluoride levels in the study areas and population. Water iodine ($\mu\text{g/L}$): 128.6; 1100	Age
Yasmin et al. (2013)	Cross-sectional	India	145 subjects (43 children, 54 men and 48 women)	Water [F] (mg/L): 0.49; 2.82 Urinary [F] (mg/L): 0.32; 0.70 Serum [F] (mg/L): 0.05; 0.09	Fluoride ion selective electrode (Orion 9690)	Mean (SE) total T3 (pg/dL): Men: 1.12 (0.08); 1.85 (0.12) Women: 1.14 (0.09); 1.94 (0.12) Children: 0.65 (0.05); 2.65 (0.22) Mean (SE) total T4 ($\mu\text{g/L}$): Men: 9.59 (0.45); 10.35 (0.78) Women: 10.44 (0.80); 10.41 (0.82) Children: 9.25 (0.63); 13.93 (0.92) Mean (SE) TSH (mIU/L):	ELISA reader (ERBA Lisa scan EM)	No assessment	Age and sex

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Table 1 (continued)

Reference	Study design	Country	Population characteristics at baseline	Exposure categories (unit)	Exposure assessment method	Outcome	Outcome assessment method	Assessment of iodine status	Adjustments
Zhang et al. (2015)	Cross-sectional	China	180 children aged 10–12 years	Water [F] (mg/L): 0.63; 1.40 Urinary [F] (mg/L): 1.10; 2.40 Serum [F] (mg/L): 0.06; 0.18	Fluoride Ion selective electrode method (ion analyzer EA940)	Men: 2.75 (0.47); 2.42 (0.29) Women: 2.58 (0.29); 2.64 (0.28) Children: 0.47 (0.08); 3.63 (0.28) Mean (SD) total T3 (ng/mL): 2.15 (0.42); 2.22 (0.36) Mean (SD) total T4 (ng/mL): 90.79 (18.85); 85.65 (16.80) Median (IQR) TSH (μ IU/mL): 2.59 (2.24–3.16); 3.11 (2.60–4.09)	Standard radioimmunoassay (RIA)	None of the study areas 2 sites was delimited into endemic areas of iodine deficiency disorders.	Age, sex, and iodine status
Zulfiqar et al. (2019)	Cross-sectional	Pakistan	134 children aged 7–18 years	Water [F] (ng/L): 0.54; 4.66 Urinary [F] (ng/L): 1.52; 2.59 Serum [F] (ng/L): 0.05; 0.06	Fluoride ion selective electrode (F-ISE)	Mean (SD) free T3 (pmol/L): 5.09 (0.53); 5.06 (0.60) Mean (SD) free T4 (pmol/L): 17.55 (3.43); 18.30 (2.47) Mean (SD) TSH (mIU/L): 2.36 (1.06); 3.20 (2.20)	Competitive Radioimmunoassay (RIA) for T3 and T4, and sandwich-type Immunoradiometric assay (IRMA) for TSH	No assessment	Age
Zulfiqar et al. (2020)	Cross-sectional	Pakistan	190 children aged 7–18 years	Water [F] (mg/L): 0.54; 6.23 Urinary [F] (mg/L): 1.52; 3.38 Serum [F] (mg/L): 0.05; 0.21	Fluoride ion selective electrode (F-ISE)	Mean (SD) free T3 (pmol/L): 5.09 (0.53); 5.57 (1.01) Mean (SD) free T4 (pmol/L): 17.55 (3.43); 16.64 (3.78) Mean (SD) TSH (mIU/L): 2.36 (1.06); 4.41 (2.29)	Competitive Radioimmunoassay (RIA) for T3 and T4, and sandwich-type Immunoradiometric assay (IRMA) for TSH	No assessment	Age

Abbreviations: β = mean difference; CI 95% = confidence interval at 95%; Ecobody index = Tvol/body surface area (mL/m²); F = fluoride; [F] = fluoride concentration; IQR = interquartile range; Q = quartile; NR = not reported; ref = reference; SD = standard deviation; SE = standard error; T3 = triiodothyronine; T4 = thyroxine or tetraiodothyronine; TSH = thyroid-stimulating hormone; Tvol = thyroid volume; ¹ Such information has been considered in the study but the related data were not suitable for inclusion in the analyses due to missing units of measurement of outcome.

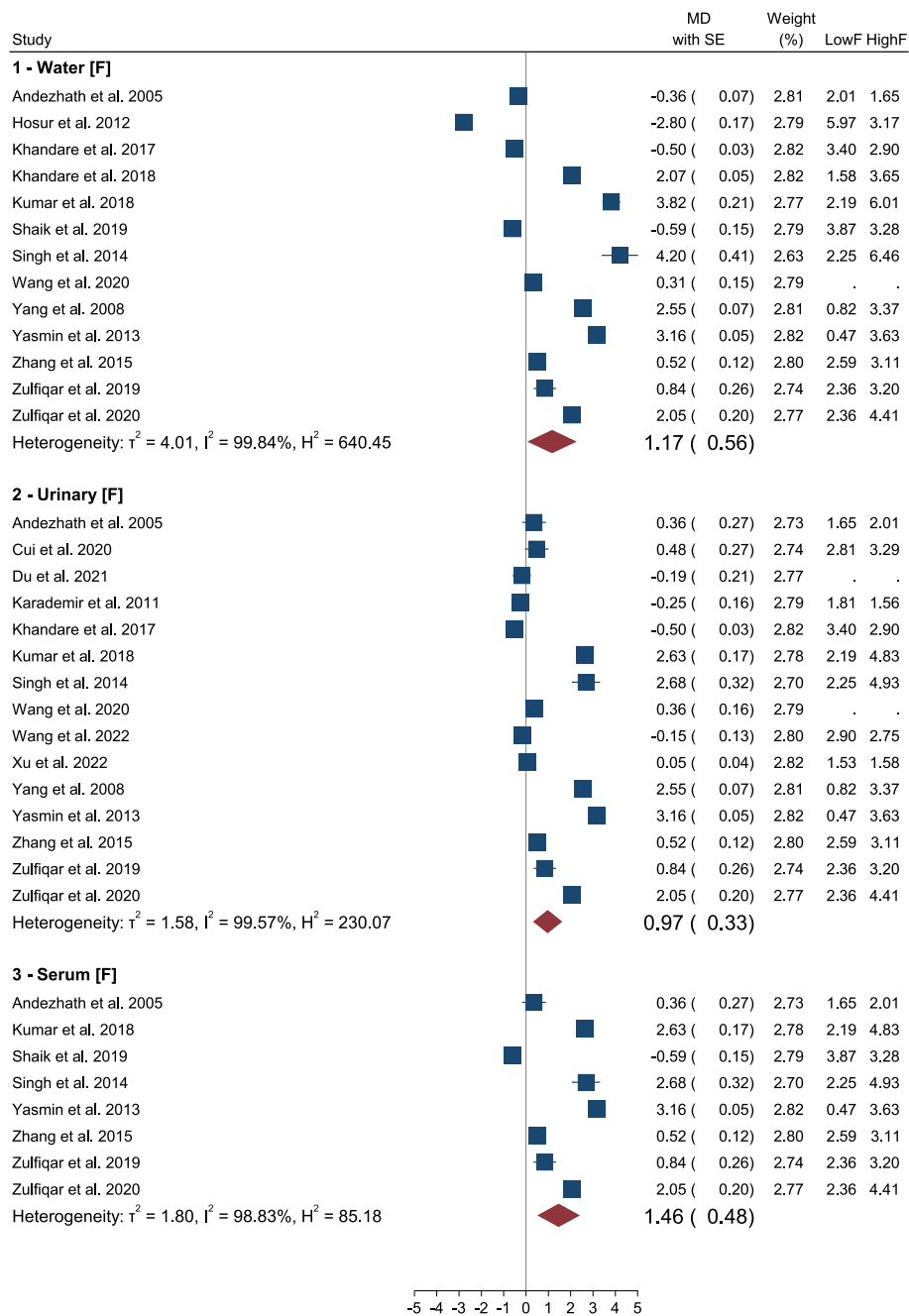


Fig. 2. Forest plot of the included studies regarding differences of TSH ($\mu\text{IU/mL}$) in children according to the highest and the lowest fluoride (F) exposure category (mg/L). The squares represent mean differences (MD) between the highest and the lowest exposure category and horizontal lines their standard errors (SE). The LowF and HighF columns report mean TSH values in the lowest and the highest fluoride exposure category, respectively. The area of each square is proportional to the weight of the study in the meta-analysis. The diamonds represent the summary mean difference, and the solid vertical line represents null value. Inverse-variance estimation method used for study weighting.

except for total T4, for which the summary mean differences were 0.82, -0.17 , $-0.51 \mu\text{g/dL}$ for drinking water ($n = 4$), urinary ($n = 5$), and serum ($n = 1$) fluoride exposure, respectively. Finally, there was some evidence of publication bias regarding thyroid hormones, both free and total (Supplementary Figs. S9–S12).

We also computed study-specific and summary mean differences of TSH and thyroid hormones in adults (≥ 19 years), comparing the highest versus the lowest fluoride categories and according to the type of exposure assessment method, which are shown in Supplementary Figs. S13–S16. TSH mean difference was $0.82 \mu\text{IU/mL}$ for water fluoride ($n = 4$), $0.89 \mu\text{IU/mL}$ for urinary fluoride ($n = 3$), $0.53 \mu\text{IU/mL}$ for serum

fluoride ($n = 3$) and $2.00 \mu\text{IU/mL}$ for daily fluoride intake ($n = 1$), while differences for thyroid hormones across exposure categories were considerably lower. Total T3 mean differences were -0.12 ng/mL ($n = 3$), -0.17 ng/mL ($n = 2$), -0.17 ng/mL ($n = 2$) for water, urinary and serum fluoride, respectively, while calculation of study-specific and summary mean differences of free T3 could not be performed due to limited data availability. Moreover, summary total T4 mean differences were close to zero for water ($n = 3$), urinary ($n = 3$), and serum fluoride ($n = 2$), while for daily fluoride intake ($n = 1$) was $0.35 \mu\text{g/day}$. Data on free T4 in adults were reported only by Hall et al. (2023), resulting in summary mean differences close to zero. The study-specific and

summary mean differences of TSH and thyroid hormones in adults, considering only “Low” and “Some concerns” risk of bias studies (n = 2), are displayed in [Supplementary Fig. S17](#) and one of the studies in this forest plot is the one published by [Hall et al. \(2023\)](#), which is the only study in our meta-analysis having a cohort design and pregnant women as the studied population. Regarding publication bias for TSH in adults ([Supplementary Fig. S18](#)), there seemed to be some evidence of publication bias.

Finally, in [Supplementary Fig. S19](#), we report the forest plot of the 2 studies regarding differences of TSH and thyroid hormones in the

general population (without distinction between children and adults), according to the highest and the lowest fluoride exposure category, stratified by exposure and outcome. Considering the analyses for thyroid diseases ([Supplementary Fig. S20](#)), summary RRs for goiter in children was well above unity, i.e., 1.79 (95% CI: 1.18; 2.73) for the highest versus the lowest drinking water fluoride category (n = 3), and 7.93 (95% CI: 1.93; 32.59) for urinary fluoride (n = 1). RRs for thyroid disease in adults were computed only for water fluoride exposure due to lack of data for other exposure types, and were 7.38 (95% CI: 1.17; 46.53) for goiter (n = 1) and 1.62 (95% CI: 1.36; 1.93) for

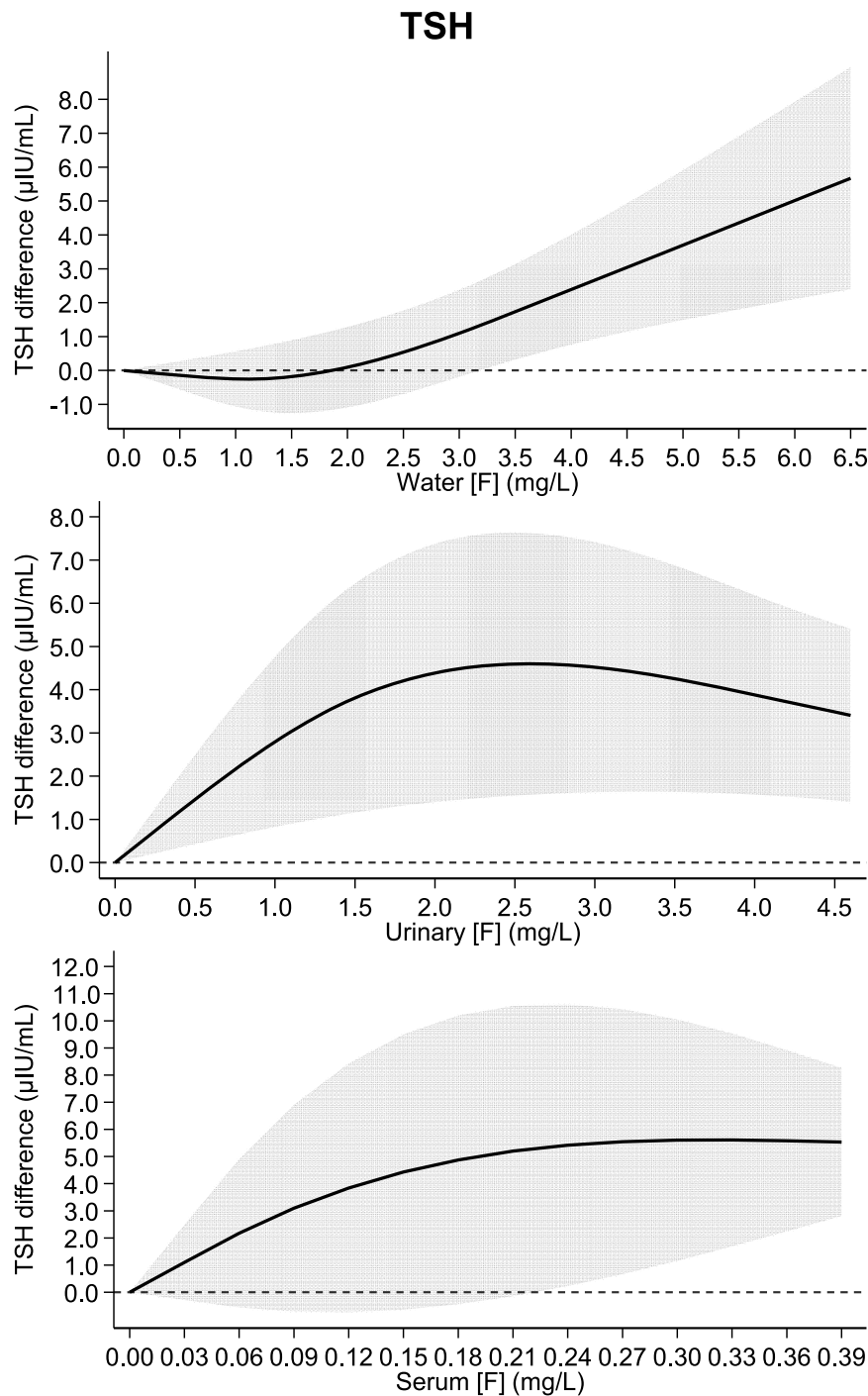


Fig. 3. Dose-response meta-analysis of TSH concentrations and exposure to fluoride (F) from drinking water (n = 13), urinary fluoride (n = 15) and serum fluoride (n = 8) in children. TSH difference curve (black solid line) with 95% confidence interval (grey area).

hypothyroidism (n = 1). Regarding the studies that considered both adults and children as population, without any distinction, the RR for goiter with exposure to fluoride in water (n = 4) was 2.63 (95% CI: 0.63; 10.91), while a RR of 0.09 (95% CI: 0.07; 0.11) was reported in the only study addressing ‘unspecified’ thyroid condition. Similar positive results were also observed excluding studies with the highest risk of bias, i.e., “High” and “Very high” risk of bias studies (Supplementary Fig. S21).

The dose-response meta-analysis based on a non-linear restricted cubic spline regression model was only conducted for studies assessing TSH levels (Fig. 3) and total T3 and T4 (Fig. 4) in children, given the

limited number of studies available for other age groups and for other endpoints. The dose-response curve for water fluoride exposure (n = 13) showed no change in TSH concentrations in the lowest exposure range, while at a drinking water fluoride concentration around 2.0 mg/L, TSH levels started to increase, with a positive and approximately linear pattern. Compared with the analysis based on water fluoride concentrations, the shapes of the dose-response curves based on both urinary (n = 15) and serum fluoride (n = 8) showed moderately different patterns. TSH levels were positively associated with fluoride already at very low exposure and up to 2.5 mg/L for urinary and 0.2 mg/L for serum,

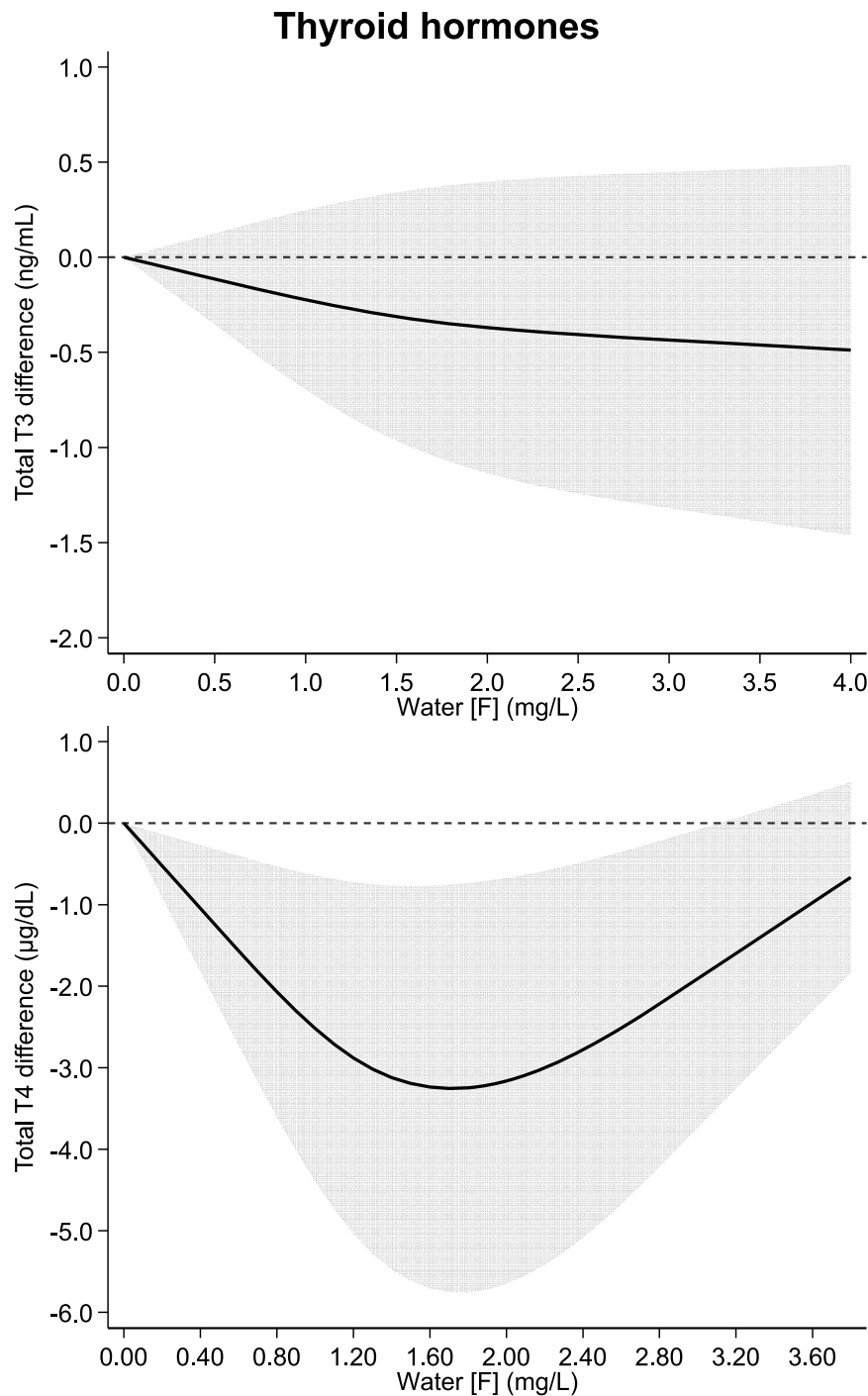


Fig. 4. Dose-response meta-analysis of total T3 (n = 6) and total T4 (n = 6) concentrations and exposure to fluoride (F) from drinking water in children. Difference curve (black solid line) with 95% confidence interval (grey area).

when both curves started to flatten, with even an indication of a downward pattern for urinary fluoride. The dose-response curves for total T3 (n = 6) and total T4 (n = 6) concentrations in children exposed to fluoride from drinking water are displayed in Fig. 4. Fluoride exposure was negatively associated with T3 and T4 concentrations already at very low levels and up to 2.0 mg/L, when the T3 curve started to flatten, while for T4 there was an upward pattern, resulting in a U-shaped curve.

We also performed sensitivity analyses excluding the studies belonging to the two categories with the highest risk of bias, i.e., “High” and “Very high”. Such subgroup analyses for TSH in children (Fig. 5)

revealed some changes in the shape of the spline curves for all the three indicators of fluoride exposure. The curve for water fluoride had a less steep slope, as well as a slightly higher threshold level (2.5 mg/L instead than the around 2.0 mg/L of the overall analysis), above which TSH started to increase. Conversely, the curve based on urinary fluoride flattened above 2.5 mg/L of the biomarker but lacked a downward inflection, and the one for serum fluoride had an almost linear, positive pattern. Fig. 6 displays sensitivity analyses with “Low” and “Some concerns” risk of bias studies for total T3 (n = 4) and total T4 (n = 4) concentrations in children exposed to fluoride from drinking water. Both

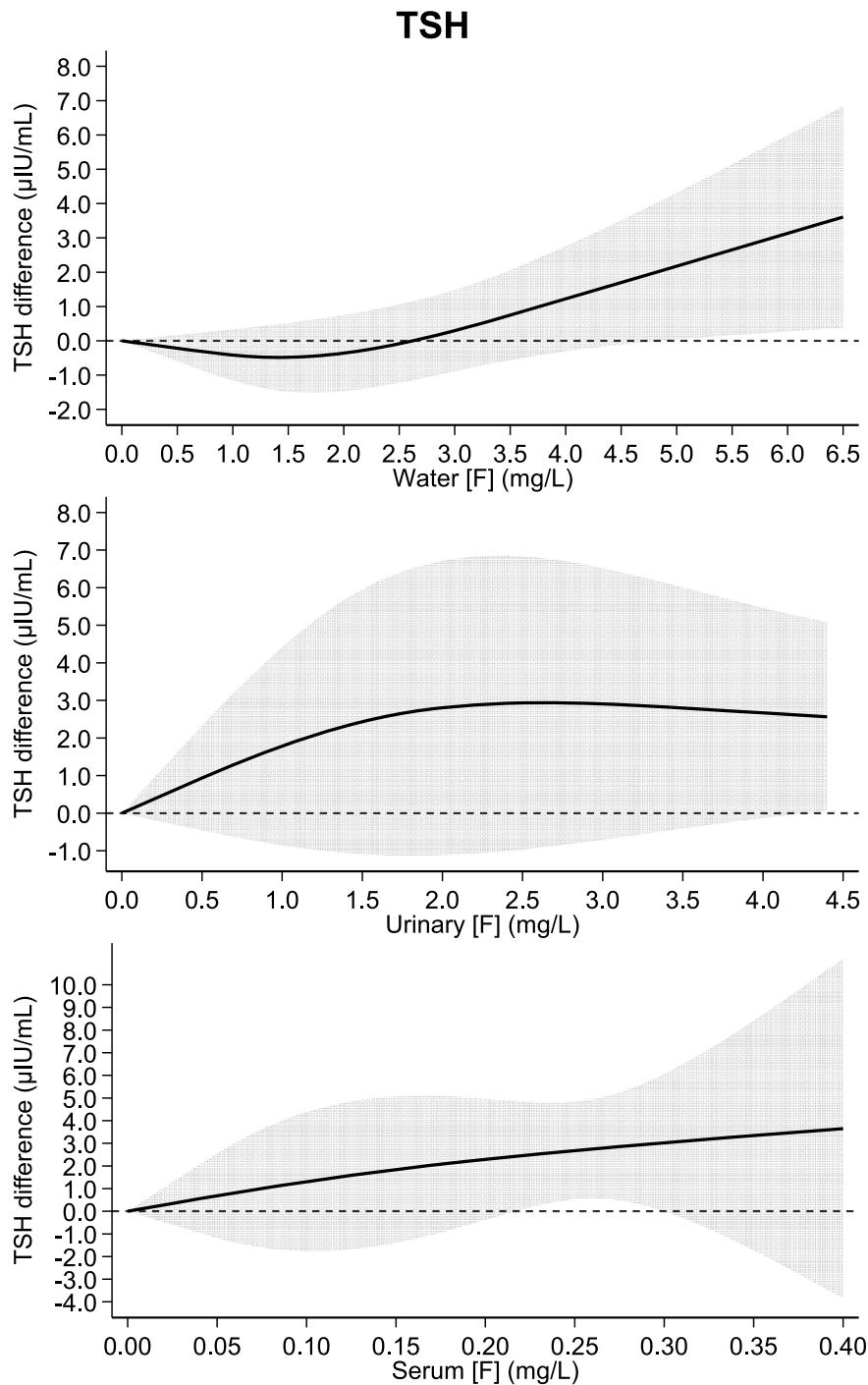


Fig. 5. Dose-response meta-analysis of TSH concentrations and exposure to fluoride (F) from drinking water (n = 8), urinary fluoride (n = 11) and serum fluoride (n = 5) in children, only with “Low” and “Some concerns” risk of bias studies. TSH difference curve (black solid line) with 95% confidence interval (grey area).

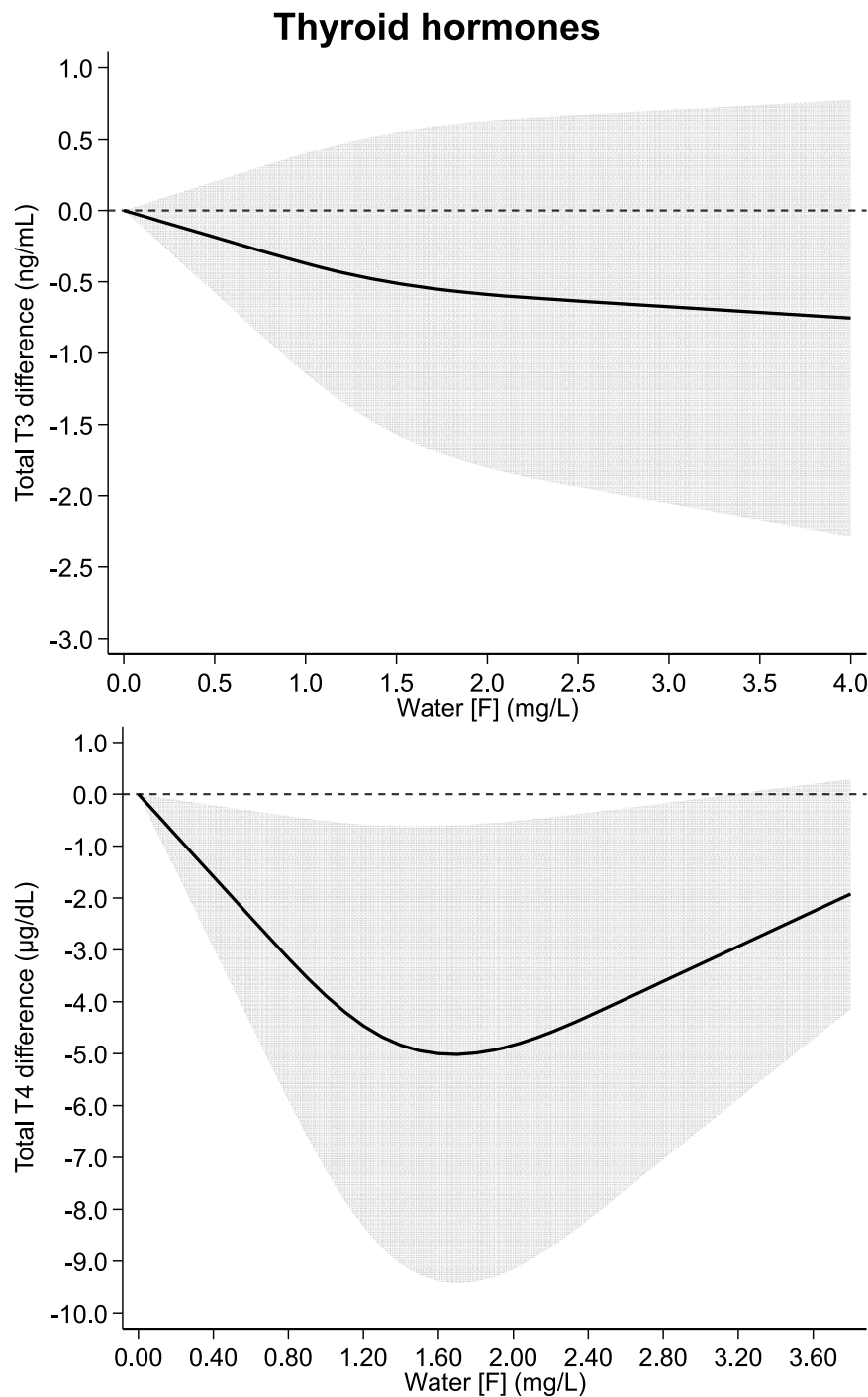


Fig. 6. Dose-response meta-analysis of total T3 (n = 4) and total T4 (n = 4) concentrations and exposure to fluoride (F) from drinking water in children, only with “Low” and “Some concerns” risk of bias studies. Difference curve (black solid line) with 95% confidence interval (grey area).

spline curves seem to have similar shapes to the ones from the overall analyses, which can be explained by the small number of studies excluded due to high risk of bias. With reference to study-specific dose-response curves for TSH concentrations in children (Supplementary Fig. S22), the dose-dependent patterns for water fluoride exposure showed substantial homogeneity, with comparable trends among them and for the overall curve, with only a few lines (n = 5) exceeding the confidence interval of the summary estimate. Conversely, analyses for both urinary and serum fluoride showed high heterogeneity, with different shapes and trends, and few of the urinary fluoride study-

specific lines included within the confidence interval of the overall curve. Similarly, the study-specific lines for total T3 concentration in children exposed to fluoride in drinking water (Supplementary Fig. S23) showed high heterogeneity while those for total T4 had U-shape trends, but with different depths of their nadirs. For both analyses, no study-specific line was outside the confidence interval.

4. Discussion

In this systematic review and dose-response meta-analysis on thyroid

function as related to fluoride exposure, we found a clear pattern of association between fluoride content in drinking water consumed by the study participants and their circulating TSH concentrations. However, this occurred only above 2 mg/L of water fluoride (2.5 mg/L when the studies with the best quality were considered), thus confirming the hypothesis of a non-linear, dose-dependent pattern of association, something suggested to occur also for the adverse effects of drinking water fluoride on children's intelligence quotient (Veneri et al., 2023b). However, in the current pooled analysis on thyroid function, the removal of studies with the lowest methodological quality had a limited impact on the results, suggesting that the effect of biases on the thyroid effect estimates was not relevant. This positive but non-linear relation between exposure to fluoride through drinking water and circulating TSH concentrations was remarkably consistent across the many studies carried out about this association and included in this dose-response analysis (Andezhath et al., 2005; Hosur et al., 2012; Khandare et al., 2017, 2018; Kumar et al., 2018; Shaik et al., 2019; Singh et al., 2014; Wang et al., 2020; Yang et al., 2008; Yasmin et al., 2013; Zhang et al., 2015; Zulfiqar et al., 2019, 2020), further strengthening the possibility of a causal link.

Conversely, studies on TSH as related to biomarkers of fluoride exposure, i.e., urinary and serum fluoride, did not yield a pattern of association similar to that for water fluoride. The shape of the curve indicates a no-threshold positive association starting from the lowest exposure levels, and flattening at the highest exposure range, with the exception of studies of the highest methodological quality based on serum fluoride, for which the pattern of association was almost linear. Such discrepancies between fluoride exposure through drinking water and biomarkers could be due to different reasons, including the lower number of studies available for serum fluoride, possible differences among the analytical methods used in the included studies, or more importantly the lower reliability of studies based on biomarkers in reflecting real internal exposure (particularly for urinary fluoride), due to individual changes in fluoride absorption, metabolism and excretion. In addition, assessing fluoride exposure through a long-term, stable, and major determinant of intake, such as fluoride in drinking water, could be more reliable than considering more unstable and short-term indicators like urinary and serum fluoride levels (Hall et al., 2023), unless for very high exposures, when biomarkers tend to be considerably associated with the environmental sources of exposure. In fact, while residential drinking water fluoride level and water consumption tend to be substantially stable over time, fluoride intake with foods, beverages, or dental products can considerably vary. This may induce non-differential misclassification of antecedent exposure when using short-term biomarkers, biasing the risk and effect estimates towards the null. Demographic factors such as age and sex, lifestyle factors such as smoking, alcohol consumption and regular tooth-brushing, and dietary and metabolic factors influencing fluoride absorption and metabolism may also modify the association between fluoride exposure (as that occurring through drinking water or other sources) and biomarkers such as serum and urinary fluoride concentrations (Kishor et al., 2023; Maguire and Zohoori, 2013; Riddell et al., 2021). This is also reflected by the null or low correlation between fluoride exposure and fluoride biomarkers found in some of the studies (Carwile et al., 2020; Lavalle-Carrasco et al., 2023; Saad et al., 2022; Zohoori et al., 2019). Overall, the limitations of biomarkers (unless based on repetitive samples) in adequately reflecting long-term fluoride exposure could explain the different patterns of the dose-response associations for individual studies based on urinary or serum fluoride concentrations, as compared to the substantially homogeneous dose-response curves across studies on drinking water fluoride levels, and the different results for the various exposure indicators within single epidemiologic studies (Hall et al., 2023; Malin et al., 2018; Riddell et al., 2019; Yu et al., 2018b) as does the current meta-analysis. Interestingly, a dose-response pattern comparable to that found in our pooled analysis emerged from a Chinese cross-sectional study (Yu et al., 2018b) assessing the relation of water and urinary fluoride with dental

fluorosis, where a threshold was identified of slightly less than 1 mg/L of water fluoride before detecting a positive association, while the association started already at the lowest urinary fluoride concentrations (from 0.01 mg/L). Consistently, in a recently published cross-sectional analysis of a cohort study in Canada (Hall et al., 2023), no linear association emerged between urinary fluoride and risk of hypothyroidism, while such association was positive with fluoride intake through beverages (OR: 1.25; 95% CI: 0.99–1.57), and particularly with drinking water fluoride concentrations (OR: 1.65; 95% CI: 1.04–2.60).

Despite the strong association between fluoride exposure and TSH, we were unable to confirm such a clear association (expected on the opposite direction) for circulating thyroid hormones, either total or free. This may have been due to the limited number of studies that precluded a reliable analysis through a spline-based non-linear model, or to the real absence of such effects, despite the forest plot indicated some slight changes, mostly a decrease, in the circulating concentrations of these hormones. In addition, such possible effects on circulating thyroid hormones should be better appreciated at the individual level, particularly in subjects characterized by subtle thyroid hormone deficiency or located at the lowest range of such levels, these likely being the individuals most susceptible to fluoride-induced adverse effects on thyroid function. Finally, it cannot be excluded that different analytical methods for thyroid hormones might have affected comparisons across studies.

With reference to thyroid disease risk, we could retrieve too few studies for a dose-response meta-analysis. Results of such studies (Barberio et al., 2017; Day and Powell-Jackson, 1972; Eltom et al., 1984; Hong et al., 2008; Jooste et al., 1999; Lathman and Grech, 1967; Peckham et al., 2015; Siddiqui, 1960; Yang et al., 2008), either in children or in adults or in mixed populations, generally indicated a higher (in some cases much higher) risk of goiter, hypothyroidism, or thyroid diseases overall considered, with the exception of the few observations in the mixed population, showing a very inconsistent overall picture. Overall, the evidence available for thyroid disease risk as associated with fluoride exposure is too limited to draw conclusions, though there is a general indication of detrimental effects of exposure to the highest levels of fluoride occurring in the included studies. This appears also supported by biological plausibility, since laboratory and animal studies have suggested that excess fluoride exposure may decrease thyroid hormone synthesis and increase circulating TSH levels (Skórka-Majewicz et al., 2020). Fluoride may damage the proper functioning of the thyroid, interfering with Na/K-ATPase and with iodothyronine deiodinase, disrupting sensitive G-proteins of hormone receptors, mimicking TSH, and impairing T4 conversion into T3, through effects on the enzymes catalyzing deiodination i.e., iodothyronine deiodinases (Bürgi et al., 1984; Hong-liang et al., 2014; Peeters and Visser, 2000; Shashi and Singla, 2013; Skórka-Majewicz et al., 2020; Spittle, 2016; Strunecka and Strunecky, 2020; Susheela and Toteja, 2018; Waugh, 2019). Fluoride could also damage thyroid cells by determining mitochondrial swelling and disintegration, and by inducing DNA-RNA damage (Peeters and Visser, 2000; Wei et al., 2022). It may also have adverse effects on thyroid cells and thyroid follicular morphology, altering thyroid structure (Liu et al., 2016; Sarkar and Pal, 2014; Yu et al., 2018a).

We must outline a few limitations of our assessment. First, some the epidemiologic studies did not provide the data to assess the dose-response relation between fluoride exposure and thyroid function and disease (for instance reporting only linear regression coefficients for the overall association). Secondly, it is known that both excess and deficient iodine intake may affect thyroid function and morphology, as well as could interact with fluoride in modifying the impact of both elements (Jiang et al., 2016; Malin et al., 2018). However, such potential confounding effect and interactions have not been generally addressed in the included studies, with some exceptions. Some studies investigated subjects with homogeneous iodine exposure while others determined iodine exposure in the same categories of fluoride exposure, most of which finding changes in the same direction of iodine and fluoride

levels. Only one study (Du et al., 2021) adjusted for urinary iodine in the multivariable analysis, finding no association between urinary fluoride and TSH. In addition, there is some evidence of susceptibility of pregnant women to fluoride-induced hypothyroidism but based on one study only (Hall et al., 2023). More data are clearly required to better investigate the relation between fluoride exposure and thyroid function and disease risk, considering the overall nutritional status in relation to iodine and other trace elements as well as environmental pollutants possibly associated with thyroid function and disease (Chamot et al., 2023; Ge et al., 2023; Kim et al., 2022; Loomba et al., 2020; Urbano et al., 2022a, 2022b). In addition, fluoride toxicity on thyroid function, disease risk, and morphology could theoretically be enhanced in individuals carrying some functional alterations and impairment of the gland, or at an early stage of thyroid disease, and such a possible higher susceptibility should be investigated in-depth in epidemiologic and clinical studies. Genetic factors should also be taken into consideration when assessing the risk of any environmental exposure, including fluoride (Chakraborty et al., 2022; Cui et al., 2018; González-Casamada et al., 2022), and the availability of data with reference to fluoride overexposure and its effects on the thyroid gland is unfortunately very poor, being limited to few studies with inconclusive results (Wang et al., 2022; Xu et al., 2022; Zhang et al., 2015). Finally, since all the included studies are observational, the potential impact of unmeasured confounding cannot be ruled out, adding caution to the interpretation of the individual studies and of our pooled analysis. However, most of the studies appear to have considered major factors affecting TSH levels, such as age and sex (Xing et al., 2021).

Our findings are of considerable public health relevance given the importance of thyroid function for human health (including cognitive neurodevelopment), and the rather frequent occurrence of high fluoride concentrations in groundwaters in several regions of the world, including Africa (Rift Valley like Tanzania, Kenya and Ethiopia), Asia, and America. The World Health Organization (WHO) has estimated that around 260 million people inhabit locations having excessive fluoride levels in drinking water (>1.5 mg/L) globally (Jha and Tripathi, 2021). Our findings are also relevant to the public health issue of water fluoridation in order to prevent dental disease and caries in particular, given the uncertainties and the controversies surrounding this topic and the need of a comprehensive risk assessment of such type of intervention (Till and Green, 2021).

In conclusion, our systematic review and dose-response meta-analysis showed that at the highest levels of naturally occurring fluoride exposure there are detrimental effects on thyroid function and possibly thyroid disease risk, whose most evident and consistent finding is a dose-dependent increase in TSH concentrations associated with consumption of drinking water above 2.5 mg/L of fluoride.

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CRediT authorship contribution statement

Inga Iamandii: Data curation, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Lisa De Pasquale:** Data curation, Methodology, Writing - original draft, Writing - review & editing. **Maria E. Giannone:** Methodology, Writing - review & editing. **Federica Veneri:** Conceptualization, Writing - review & editing. **Luigi Generali:** Writing - review & editing. **Ugo Consolo:** Writing - review & editing. **Linda S. Birnbaum:** Writing - review & editing. **Jacqueline Castenmiller:** Writing - review & editing. **Thorallur I. Halldorsson:** Writing - review & editing. **Tommaso Filippini:** Conceptualization, Data curation, Methodology, Supervision, Writing - original draft, Writing - review & editing. **Marco Vinceti:** Conceptualization, Methodology, Supervision, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.envres.2023.117759>.

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Maternal Urinary Fluoride and Child Neurobehavior at Age 36 Months

Ashley J. Malin, PhD; Sandrah P. Eckel, PhD; Howard Hu, MD, MPH, ScD; E. Angeles Martinez-Mier, PhD, DDS, MSD; Ixel Hernandez-Castro, PhD; Tingyu Yang, MS; Shohreh F. Farzan, PhD; Rima Habre, ScD; Carrie V. Breton, ScD; Theresa M. Bastain, PhD

Abstract

IMPORTANCE Recent studies in Canadian and Mexican populations suggest an association of higher prenatal fluoride exposure with poorer neurobehavioral development, but whether this association holds for US-based populations is unknown.

OBJECTIVE To examine associations of third trimester maternal urinary fluoride (MUF) with child neurobehavior at age 3 years in the US.

DESIGN, SETTING, AND PARTICIPANTS This prospective cohort study utilized urine samples archived from 2017 to 2020 and neurobehavioral data assessed from 2020 to 2023 from the Maternal and Developmental Risks from Environmental and Social Stressors (MADRES) pregnancy cohort, which consisted of predominately Hispanic women residing in Los Angeles, California. Cohort eligibility criteria at recruitment included being 18 years of age or older, less than 30 weeks' gestation, and a fluent English or Spanish speaker. Exclusion criteria included having a disability preventing participation or provision of informed consent, being HIV positive or incarcerated, and having a multiple gestation pregnancy. There were 263 mother-child pairs who completed the 3-year study visit. In this analysis, women who reported prenatal smoking were excluded. Data analysis was conducted from October 2022 to March 2024.

EXPOSURE Specific gravity-adjusted MUF (MUF_{SG}), a biomarker of prenatal fluoride exposure.

MAIN OUTCOMES AND MEASURES Neurobehavior was quantified using the Preschool Child Behavior Checklist (CBCL), which included composite scores for Total Problems, Internalizing Problems, and Externalizing Problems. CBCL composite T scores range from 28 to 100. T scores from 60 to 63 are in the borderline clinical range, whereas scores above 63 are in the clinical range. Linear and logistic regression models adjusted for covariates were conducted.

RESULTS A total of 229 mother-child pairs (mean [SD] maternal age, 29.45 [5.67] years; 116 female children [50.7%] and 113 male children [49.3%]) who had MUF_{SG} measured were included in the study. Median (IQR) MUF_{SG} was 0.76 (0.51-1.19) mg/L, and 32 participants (14.0%) had a Total Problems T score in the borderline clinical or clinical range. A 1-IQR (0.68 mg/L) increase in MUF_{SG} was associated with nearly double the odds of the Total Problems T score being in the borderline clinical or clinical range (odds ratio, 1.83; 95% CI, 1.17-2.86; $P = .008$), as well as with a 2.29-point increase in T score for the Internalizing Problems composite ($B = 2.29$; 95% CI, 0.47-4.11; $P = .01$) and a 2.14-point increase in T score for the Total Problems composite ($B = 2.14$; 95% CI, 0.29-3.98; $P = .02$).

CONCLUSIONS AND RELEVANCE In this prospective cohort study of mother-child pairs in Los Angeles, California, prenatal fluoride exposure was associated with increased neurobehavioral problems. These findings suggest that there may be a need to establish recommendations for

(continued)

Key Points

Question Is prenatal fluoride exposure associated with child neurobehavior in a US-based sample?

Findings In this cohort study of 229 pregnant women and their children, a 0.68 mg/L (ie, 1 IQR) increase in specific gravity-adjusted maternal urinary fluoride during pregnancy was associated with nearly double the odds of T scores for total child neurobehavioral problems being in the borderline clinical or clinical range.

Meaning These findings suggest that prenatal fluoride exposure may increase risk of neurobehavioral problems among children living in an optimally fluoridated area in the US.

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

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Abstract (continued)

limiting fluoride exposure during the prenatal period.

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Introduction

Fluoride levels in community drinking water systems in the US have been adjusted to prevent dental caries since 1945.¹ Currently, 73% of the US receives fluoridated water at a targeted concentration of 0.7 mg/L (to convert to millimoles per liter, multiply by 0.05263). This has been considered optimal for preventing dental caries while minimizing risk of adverse systemic health effects.² Most of Los Angeles County, California is at least partially fluoridated.^{3,4} Fluoride can also naturally occur in soil and rock or be released into the environment via industrial processes.^{5,6}

It is widely established that exposure to high fluoride levels can adversely affect neurodevelopment⁷; however, findings from recent studies conducted in Mexico and Canada⁸⁻¹¹ suggest that fluoride exposure at lower US-relevant levels may also be associated with poorer neurodevelopment. Specifically, higher prenatal fluoride exposure in Canada and/or Mexico has been associated with lower IQ among children aged 3 to 4 years in Canada¹⁰ and children aged 6 to 12 years in Mexico,⁹ increased symptoms of attention-deficit/hyperactivity disorder (ADHD) among children aged 6 to 12 years,¹² poorer executive function among children aged 3 to 5 years,¹³ and poorer performance on measures of global cognition among 12- and 24-month-old boys.¹⁴ A recent systematic review conducted by the National Toxicology Program reported “with moderate confidence that higher fluoride exposure...is consistently associated with lower IQ in children.”¹⁵ The report¹⁵ also highlighted the lack of US studies investigating associations of fluoride exposure with neurodevelopment or cognition and stated that US studies would be valuable. To our knowledge, we conducted the first, US-based study to examine associations of prenatal fluoride exposure with child neurobehavioral outcomes.

Methods

Study Design and Participants

This cohort study was approved by the institutional review boards at The University of Southern California and The University of Florida and followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline. This study included mother-child pairs from the Maternal and Developmental Risks from Environmental and Social Stressors (MADRES) cohort.¹⁶ MADRES is a prospective pregnancy cohort consisting of 1065 predominately Hispanic women of low socioeconomic status residing in urban Los Angeles, California.¹⁶ Briefly, in 2015, pregnant women were recruited from prenatal care clinicians in Los Angeles serving predominantly medically underserved communities and provided written informed consent. Eligibility criteria include being 18 years of age or older, less than 30 weeks' gestation at the time of recruitment, and being able to speak English or Spanish fluently. Exclusion criteria included having a multiple gestation pregnancy; being HIV positive; having a physical, mental, or cognitive disability that would prevent participation or provision of informed consent; and current incarceration.¹⁶ The current study included mother-child pairs from the MADRES prospective cohort who had maternal urinary fluoride (MUF) measured during the third trimester of pregnancy and child scores on the Preschool Child Behavior Checklist (CBCL) for ages 1.5 to 5 years at age 36 months (eFigure 1 in Supplement 1).

Exposure

Urinary Fluoride

Single spot urine samples were collected from MADRES participants during the third trimester of pregnancy (from 2017-2020). The mean (range) gestational age at third trimester urine collection was 31.6 (26.9-36.0) weeks. MUF was measured at the Oral Health Research Institute at the Indiana University School of Dentistry using the Martinez Mier et al modification^{17,18} of the hexamethyldisiloxane microdiffusion method of Taves et al¹⁹ (see the eMethods in [Supplement 1](#) for additional details). MUF measurements were adjusted for specific gravity (MUF_{SG}). Urinary fluoride was utilized because it provides a reliable measure of total fluoride intake. It is also the most widely employed measure of individual fluoride exposure in epidemiological studies, including those assessing neurodevelopment.^{10-12,20,21}

Outcomes

We examined child neurobehavioral problems. These included internalizing and externalizing symptoms and symptoms consistent with *Diagnostic and Statistical Manual of Mental Disorders* (Fifth Edition [*DSM-5*]) diagnostic categories.

Preschool CBCL for Ages 1.5 to 5 Years

Child neurobehavioral outcomes were assessed from 2020 to 2023 via the Preschool CBCL, a valid measure of neurobehavior.²²⁻²⁴ The Preschool CBCL is a parent-reported measure of 99 items that was administered in MADRES when the child was approximately 36 months old. Children were rated on the CBCL by their mothers. The CBCL is available in English and Spanish. CBCL scores comprise 7 syndrome scales (Emotionally Reactive, Anxious-Depressed, Somatic Complaints, Withdrawn, Sleep Problems, Attention Problems, and Aggressive Behavior) characterizing problems that tend to co-occur together. The CBCL also includes 5 *DSM-5*-oriented scales that are comprised of items determined to be consistent with *DSM-5* diagnostic categories (Depressive Problems, Anxiety Problems, Oppositional Defiant Problems, Autism Spectrum Problems, and ADHD Problems). Scores on CBCL syndrome scales are grouped to produce an Internalizing Problems composite score and Externalizing Problems composite score. Scales that focus primarily on issues within the self comprise the Internalizing Problems composite. Conversely, scales that focus on other-directed problems and expectations for the child comprise the Externalizing Problems composite. Lastly, a Total Problems composite score is calculated by summing scores on all 99 items.²⁴ Internalizing Problems, Externalizing Problems, and Total Problems composite T scores range from 28 to 100. T scores ranging from 60 to 63 are in the borderline clinical range, whereas those above 63 are in the clinical range.²⁴ We calculated 2-category clinical index variables of normal vs borderline clinical or clinical for statistical analyses for each composite variable (see the eMethods in [Supplement 1](#) for additional details about the CBCL scales).

Covariates

Covariates were selected using a directed acyclic graph (eFigure 2 in [Supplement 1](#)), and included maternal age (continuous), education (less than 12th grade, completed 12th grade, some college or technical school, completed college, and some graduate training), ethnicity by nativity (non-Hispanic, US-born Hispanic, or non-US-born Hispanic), marital status (decline to answer, married, living together, never married and single, divorced or separated, or widowed), prepregnancy body mass index (continuous; calculated as weight in kilograms divided by height in meters squared) and prenatal household income (unknown, <\$15 000, \$15 000-\$29 999, \$30 000-\$49 999, \$50 000-\$99 999, and ≥\$100 000), as well as child sex. Categories for ethnicity by nativity were defined by study principal investigators, and ethnicity was included because it has been shown to be associated with fluoride exposure and neurodevelopment. We adjusted for ethnicity as a proxy for structural racism rather than as a biological difference. We recoded marital status based on cohabitation status (eMethods in [Supplement 1](#)).

Statistical Analysis

Descriptive statistics were calculated for MUF_{SG}, sociodemographic variables, and scores on the CBCL. We conducted linear regression adjusted for covariates to examine associations of third trimester MUF_{SG} with CBCL composite T scores as well as raw scores on CBCL syndrome scales and DSM-5-oriented scales. Assumptions of linear regression were satisfied for models examining associations of MUF_{SG} with CBCL composite T scores; however, for several models examining associations of MUF_{SG} with CBCL syndrome scales and DSM-5-oriented scales, linear regression assumptions were not satisfied. Therefore, a natural logarithm transformation was applied and a constant of 1 was added (to account for scores of 0) to the raw scores for these scales to satisfy linear regression assumptions (see the eMethods in [Supplement 1](#) for an expanded statistical analysis plan). We also tested whether child sex modified associations of MUF_{SG} with CBCL scores by including a MUF_{SG} × sex term in regression models to be retained if statistically significant. We conducted logistic regression examining associations of MUF_{SG} with binary clinical index variables. Additionally, in sensitivity analyses, we conducted Poisson regression with robust error variances to determine the relative risk of scoring in the normal compared with borderline clinical or clinical range for clinical index variables. We also conducted binary logistic regression that included 2-category clinical index dependent variables of nonclinical (ie, normal or borderline) vs clinical for each clinical index variable. We conducted several additional sensitivity analyses that are reported in the eMethods in [Supplement 1](#). We excluded women who reported prenatal smoking (6 participants). Statistical analyses were performed using SPSS statistical software version 28 (IBM) and STATA/MP version 13.0 (Stata Corp). The criterion for statistical significance was an $\alpha < .05$. Data analysis occurred from October 2022 to March 2024.

Results

There were 229 mother-child pairs (mean [SD] maternal age, 29.45 [5.67] years; 116 female children [50.7%] and 113 male children [49.3%]) included in this study. See **Table 1** for sociodemographic characteristics and exposure variables. For a comparison of sociodemographic characteristics between the current study sample and overall MADRES cohort with a live birth, see eTable 1 in [Supplement 1](#). Most participants (192 participants) reported fasting in the third trimester for at least 8 hours. MUF_{SG} did not differ between women who reported fasting and those who did not. Median (IQR) MUF_{SG} was 0.76 (0.51-1.19) mg/L. Mean (SD) T scores were 47.69 (11.60) for the Total Problems composite, 47.13 (11.62) for the Internalizing Problems composite, and 46.48 (10.68) for the Externalizing Problems composite (**Figure**). Of all participants, 32 (14.0%) had a Total Problems T score in the borderline clinical or clinical range, 35 (15.3%) had an Internalizing Problems T score in the borderline clinical or clinical range, and 23 (10.0%) had an Externalizing Problems T score in the borderline clinical or clinical range. Descriptive statistics for CBCL syndrome and DSM-oriented scale raw scores are presented in eFigure 3, eFigure 4, and eTable 2 in [Supplement 1](#).

Associations of MUF_{SG} with CBCL composite T scores and binary clinical index variables are presented in **Table 2**. A 1-IQR (0.68 mg/L) increase in MUF_{SG} was associated with nearly double the odds of having a Total Problems T score in the borderline clinical or clinical range compared with the normal range (odds ratio [OR], 1.83; 95% CI, 1.17-2.86; $P = .008$). Additionally, a 1-IQR increase in MUF_{SG} was associated with a 2.29-point increase in Internalizing Problems T scores ($B = 2.29$; 95% CI, 0.47-4.11; $P = .01$) and 2.14-point increase in Total Problems T scores ($B = 2.14$; 95% CI, 0.29-3.98; $P = .02$). Associations of MUF_{SG} with Externalizing Problems T scores or odds of having an Internalizing Problems T score in the borderline clinical or clinical range compared with the normal range were also positive but not statistically significant (Table 2). Risk ratios were generally consistent with these ORs; however, magnitudes were smaller, and the P value for the risk ratio for the Internalizing Problems binary clinical index variable was statistically significant (eTable 3 in [Supplement 1](#)). Sensitivity analyses that included nonclinical vs clinical index dependent variables were also consistent (eTable 4 in [Supplement 1](#)).

Associations of MUF_{SG} with raw scores for CBCL syndrome scales and DSM-5-oriented scales are presented in **Table 3**. A 1-IQR increase in MUF_{SG} was associated with a 13.54% increase in raw scores for the Emotionally Reactive CBCL syndrome scale (B = 0.13; 95% CI, 0.02-0.24; P = .02), and a 19.60% increase in raw scores for the Somatic Complaints CBCL syndrome scale (B = 0.18; 95% CI, 0.07-0.28; P = .001). Additionally, a 1-IQR increase in MUF_{SG} was associated with an 11.29% increase in scores on the DSM-5-oriented Anxiety Problems scale of the CBCL (B = 0.11; 95% CI, 0.003-0.21; P = .045) and an 18.53% increase in scores on the DSM-5-oriented Autism Spectrum Problems scale of the CBCL (B = 0.17; 95% CI, 0.04-0.30; P = .009). There were no other associations of MUF_{SG} with other syndrome scales or DSM-5-oriented scales. There was no interaction between fluoride and sex.

MUF_{SG} during the first trimester was also positively associated with CBCL scores (eTable 5 and eTable 6 in Supplement 1) and when first trimester blood lead level was included as a covariate in sensitivity analyses, the magnitudes of associations became larger and previously nonsignificant

Table 1. Descriptive Statistics for Demographic and Exposure Variables

Participant characteristic	Participants, No. (%) (N = 229)	Third trimester MUF _{SG} , median (IQR), mg/L
Maternal age at consent, mean (SD), y	29.45 (5.67)	NA
Child age at Preschool Child Behavior Checklist assessment, mean (range), mo	36.02 (35.12-37.62)	NA
Child sex		
Female	116 (50.7)	0.76 (0.51-1.22)
Male	113 (49.3)	0.76 (0.51-1.16)
Pregpregnancy body mass index ^a		
Underweight (<18.5)	5 (2.2)	0.71 (0.45-1.83)
Normal (18.5-24.9)	60 (26.2)	0.78 (0.48-1.32)
Overweight (25.0-29.9)	80 (34.9)	0.78 (0.55-1.25)
Obese (≥30.0)	84 (36.7)	0.74 (0.50-1.08)
Household income, \$		
Unknown	64 (27.9)	0.74 (0.43-1.17)
<15 000	41 (17.9)	0.78 (0.51-1.12)
15 000-29 000	55 (24.0)	0.68 (0.43-0.98)
30 000-49 999	35 (15.3)	0.81 (0.52-1.24)
50 000-99 999	15 (6.6)	0.72 (0.52-0.93)
≥100 000	19 (8.3)	1.46 (0.81-1.96)
Maternal education		
<High school	54 (23.6)	0.73 (0.49-1.20)
High school	65 (28.4)	0.76 (0.52-1.08)
Some college or technical school	61 (26.6)	0.73 (0.46-0.93)
4-y of College	31 (13.5)	0.86 (0.61-1.37)
Some graduate training	18 (7.9)	1.31 (0.68-1.88)
Maternal ethnicity by nativity ^b		
Non-Hispanic	44 (19.8)	1.04 (0.72-1.80)
Non-US-born Hispanic	96 (43.2)	0.76 (0.51-1.23)
US-born Hispanic	82 (36.9)	0.69 (0.43-0.99)
Habitation status		
Cohabiting	168 (83.4)	0.76 (0.51-1.25)
Not cohabiting	48 (21.0)	0.77 (0.47-1.09)
Missing or declined to answer	13 (5.7)	0.79 (0.52-1.08)
MUF _{SG} , median (IQR), mg/dL		
First trimester ^c	0.64 (0.43-0.98)	NA
Third trimester	0.76 (0.51-1.19)	NA
Average across first and third trimester ^d	0.75 (0.52-1.11)	NA
First trimester blood lead level, median (IQR), µg/dL ^e	0.36 (0.26-0.60)	NA

Abbreviations: MUF_{SG}, maternal urinary fluoride adjusted for specific gravity; NA, not applicable.

SI Conversions: To convert fluoride to millimoles per liter, multiply by 0.05263; lead to micromoles per liter, multiply by 0.0483.

^a Body mass index was calculated as weight in kilograms divided by height in meters squared.

^b Based on 222 participants due to missing data for this variable.

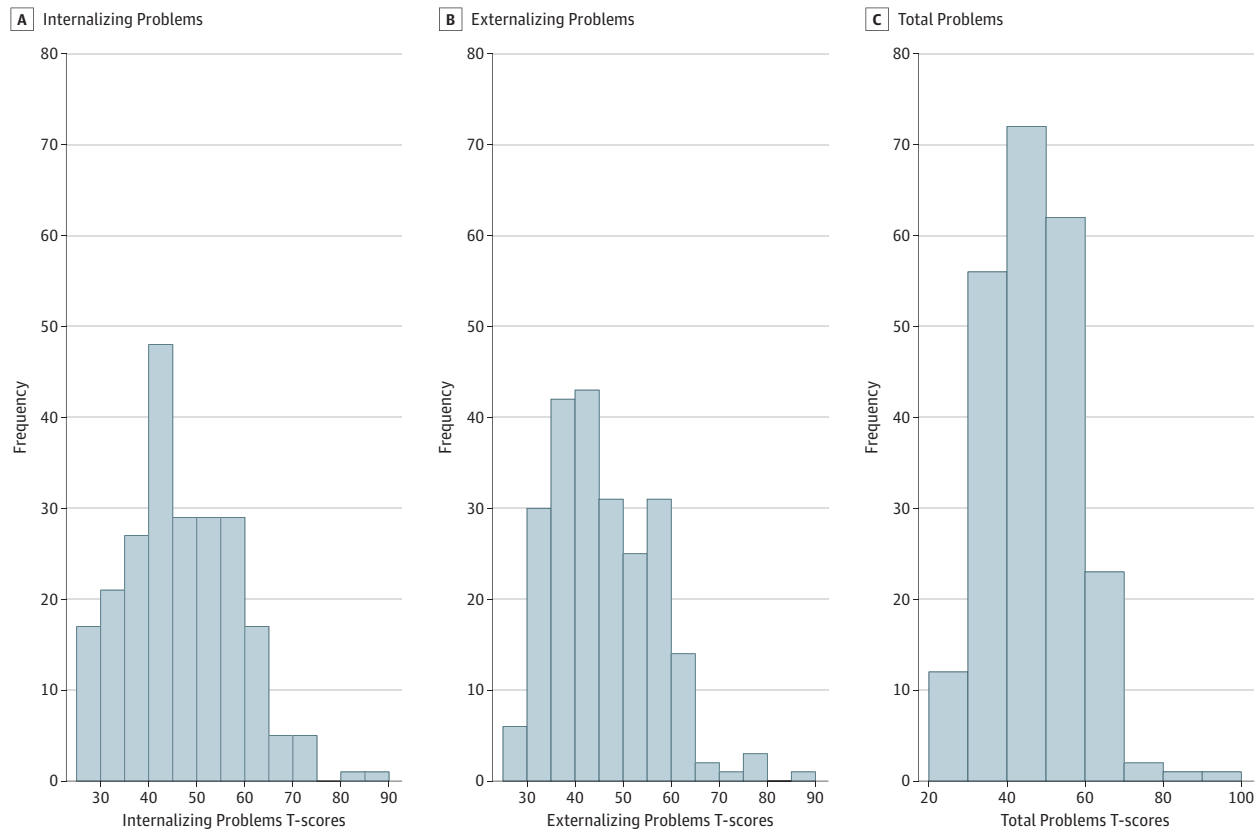
^c Based on 155 participants.

^d Based on 154 participants.

^e Based on 123 participants.

findings became significant associations in models for both the first and third trimester (eTables 7-9 in Supplement 1). Associations of MUF_{SG} with CBCL scores in the third trimester remained generally the same when examined among only the sample of women who fasted for at least 8 hours (192 participants) and when adjusting for maternal smoking during pregnancy (eTables 10-13 in

Figure. Distributions of T Scores for the Preschool Child Behavior Checklist Index Scales Among Children in the Maternal and Developmental Risks From Environmental and Social Stressors Cohort at Age 3 Years



The blue histogram bars depict the frequency of T scores among participants per Child Behavior Checklist index scale including the internalizing problems scale (A), externalizing problems scale (B), and total problems scale (C). Frequencies and percentages are based on a total of 229 participants.

Table 2. Associations of MUF_{SG} in the Third Trimester With CBCL Composite T Scores and Clinical Composite Index Variable Category^a

CBCL composite scale ^b	Composite T scores		Clinical index variable scores	
	B (95% CI)	P value	OR (95% CI) ^c	P value
Total Problems	2.14 (0.29 to 3.98)	.02 ^d	1.83 (1.17 to 2.86)	.008 ^d
Internalizing Problems	2.29 (0.47 to 4.11)	.01 ^d	1.48 (0.96 to 2.30)	.08
Externalizing Problems	1.45 (-0.27 to 3.17)	.10	1.38 (0.83 to 2.28)	.21

Abbreviations: CBCL, Preschool Child Behavior Checklist; MUF_{SG}, maternal urinary fluoride adjusted for specific gravity; OR, odds ratio.

^a Calculations are based on a total of 229 participants. B values and ORs are presented according to an IQR (ie, 0.68 mg/L [to convert to millimoles per liter, multiply by 0.05263]) increase in MUF_{SG}. Analyses were adjusted for maternal age, prepregnancy body mass index, ethnicity by nativity, maternal education, household income, maternal cohabitation, and child sex.

^b For clinical composite index scores, normal = 0 and borderline clinical or clinical = 1. Higher CBCL scores indicate more symptoms of neurobehavioral problems.

^c ORs reflect the odds of having a score in the borderline clinical or clinical range compared with the normal range.

^d Denotes statistical significance.

Supplement 1). Lastly, magnitudes of associations of mean MUF_{SG} across the first and third trimesters with CBCL scores were larger than associations of MUF_{SG} in only the third trimester with CBCL scores (eTable 14 and eTable 15 in Supplement 1).

Discussion

To our knowledge, this is the first US-based cohort study to examine associations of prenatal fluoride exposure with child neurobehavior. The study sample resided in a predominately fluoridated region and had fluoride exposures that are typical of those living in fluoridated communities in North America.^{17,25,26} For example, Till et al²⁵ reported a median MUF_{SG} of 0.77 mg/L among women living in fluoridated communities in Canada. We found that women with higher fluoride exposure during pregnancy tended to rate their children higher on overall neurobehavioral problems and internalizing symptoms, including emotional reactivity, anxiety, and somatic complaints by age 3 years. Furthermore, each 0.68 mg/L increase in MUF_{SG} was associated with nearly double the odds of total neurobehavioral problems being in the borderline clinical or clinical range. Women with higher MUF_{SG} during pregnancy also tended to rate their children higher on Autism Spectrum Disorder symptoms. The effect sizes observed in this study are sizable considering the relatively low urinary fluoride levels of participants.

Findings from this study are consistent with a recent Canadian study¹³ of over 600 maternal-child pairs in the Calgary cohort of the Alberta Pregnancy Outcomes and Nutrition study. The study found that exposure to drinking water fluoridated at 0.7 mg/L throughout pregnancy was associated with symptoms of executive dysfunction, including poorer inhibitory control, and decreased cognitive flexibility among children aged 3 to 5 years. However, associations were most pronounced among girls.¹³ Although we did not observe sex-specific associations in the current study, higher MUF_{SG} was associated with higher symptoms of Autism Spectrum Disorder and anxiety, which are also associated with poorer cognitive flexibility.²⁷⁻²⁹ Another recent study¹² conducted in the Early Life Exposures in Mexico to Environmental Toxicants (ELEMENT) cohort found that higher creatinine-adjusted MUF was associated with higher scores on measures of inattention and overall ADHD symptoms from ages 6 to 12 years. While we did not find associations of MUF_{SG} with symptoms of inattention or ADHD, this may reflect the timing of neurobehavioral assessment because symptoms of inattention are more difficult to assess (and ADHD is more difficult to diagnose) in children younger than 4 years. Although no other prospective studies, to our

Table 3. Associations of MUF_{SG} in the Third Trimester With Raw Scale Scores^a

Scale	B (95% CI)	P value	Increase in CBCL score per IQR increase in MUF _{SG} , %
Natural log transformed			
CBCL syndrome scale			
Emotionally Reactive	0.13 (0.02 to 0.24)	.02 ^b	13.54
Anxious-Depressed	0.08 (-0.03 to 0.19)	.15	8.22
Somatic Complaints	0.18 (0.07 to 0.28)	.001 ^b	19.60
Withdrawn	0.09 (-0.03 to 0.21)	.14	9.20
Sleep Problems	0.07 (-0.05 to 0.18)	.25	6.82
Attention Problems	0.06 (-0.05 to 0.16)	.28	5.76
Aggressive Behavior	0.10 (-0.03 to 0.24)	.14	10.96
CBCL DSM-5-oriented scale			
Depressive Problems	0.09 (-0.02 to 0.20)	.10	9.53
Anxiety Problems	0.11 (0.003 to 0.21)	.045 ^b	11.29
Oppositional Defiant Problems	0.08 (-0.04 to 0.19)	.20	8.00
Autism Spectrum Problems	0.17 (0.04 to 0.30)	.009 ^b	18.53
Not natural log transformed, DSM-5-oriented scale: ADHD Problems	0.41 (-0.07 to 0.88)	.10	Point increase, 0.41

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; CBCL, Preschool Child Behavior Checklist; DSM-5, Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition); MUF_{SG}, maternal urinary fluoride adjusted for specific gravity.

^a Calculations are based on a total of 229 participants. B coefficients are presented according to an IQR (ie, 0.68 mg/L [to convert to millimoles per liter, multiply by 0.05263]) increase in MUF_{SG}. CBCL scales were natural log-transformed plus a constant of 1 to satisfy assumptions of linear regression, except for the DSM-5 ADHD problems scale because linear regression assumptions were satisfied for that model. Analyses were adjusted for maternal age, prepregnancy body mass index, ethnicity by nativity, maternal education, household income, maternal cohabitation, and child sex. Higher CBCL scores indicate more symptoms of neurobehavioral problems.

^b Denotes statistical significance.

knowledge, have examined associations of prenatal fluoride exposure with CBCL scores, a recent cross-sectional study³⁰ of 12-year-old children in the Cincinnati Childhood Allergy and Air Pollution Study found that higher specific gravity-adjusted urinary fluoride levels were associated with higher somatic symptoms scores and odds of internalizing T scores being in a clinically at-risk range (defined as a T score ≥ 60) on the Behavior Assessment System for Children (Second Edition), particularly among boys. Still, an earlier study of 7- to 11-year-old children residing in Boston³¹ found no association of dental fluorosis or environmental fluoride exposure (assessed via questionnaire) with parent-reported neurobehavioral problems on the CBCL.

Other studies conducted in Canada and Mexico have found associations of higher prenatal fluoride exposure at US-population-relevant levels with poorer neurocognitive outcomes, including lower IQ.^{8-10,12,14,21} For example, a study conducted in the ELEMENT cohort found that each 0.5 mg/L increase in creatinine-adjusted MUF was associated with a more than 2-point reduction in global cognitive functioning or IQ across 3 time points during middle to late childhood.²¹ Similarly, research conducted in the Canadian Maternal-Infant Research on Environmental Chemicals cohort found that each 1 mg/L increase in MUF_{SG} was associated with a 4.49-point lower IQ score in boys.^{8,10} Taken together, the weight of the scientific literature supports an association of prenatal fluoride exposure with adverse child cognitive and neurobehavioral development in North America. Still, when considering the global body of scientific literature, there are some inconsistencies.³²⁻³⁴

It is well-established that the prenatal and early postnatal periods are windows of susceptibility for neurodevelopmental impacts of environmental toxicant exposures.^{35,36} Animal studies have delineated potential mechanisms underlying the association of prenatal fluoride exposure with neurobehavioral development. A 2022 study³⁷ found that at 90 days of age, male rats who were prenatally and perinatally exposed to relatively low fluoride levels exhibited altered neurobiochemical markers of oxidative damage, glutamate metabolism, and acetylcholinesterase activity. Another recent study³⁸ found that at 90 days of age, female rats exposed to low fluoride levels during gestation and lactation exhibited decreased messenger RNA expression of the $\alpha 7$ nicotinic acetylcholine receptor ($\alpha 7$ nAChR) and reduced hippocampal catalase activity (an indicator of oxidative stress). Neurochemical changes observed in both studies^{37,38} have been replicated in other animal as well as in vitro studies that included high fluoride exposures.³⁹⁻⁴¹ Interestingly, both oxidative stress and alterations of the $\alpha 7$ nAChR in particular have been implicated in the pathophysiology of neurodevelopmental disorders, including Autism Spectrum Disorder.^{42,43} Furthermore, alterations in glutamate pathways have been implicated in the cause and treatment of anxiety disorders.⁴⁴ Prenatal fluoride exposure may also adversely affect neurodevelopment and cognition by causing mitochondrial dysfunction which can increase oxidative stress, blocking autophagosome-lysosome fusion which can contribute to cellular damage, and by causing synaptic dysfunction.⁴⁵⁻⁴⁷ Additionally, prenatal fluoride exposure, even at low levels, can suppress maternal thyroid gland activity which can contribute to cognitive and neurobehavioral problems in offspring.^{48,49}

Strengths and Limitations

There are notable strengths of the current study, including the use of individual biomarker measures of exposure assessment that provide an estimate of fluoride intake from all sources, and the adjustment for a breadth of covariates associated with fluoride exposure, metabolism, and neurodevelopment. Additionally, our study addressed a limitation of prior studies on fluoride exposure and neurodevelopment by including a sample of predominantly fasting pregnant women, which can be difficult to achieve. However, there are also limitations. First, we measured fluoride in spot samples rather than 24-hour urine samples, which can be influenced by daily behaviors (eg, food and beverage consumption or use of fluoridated dental products), and therefore increase random error. Still, the inclusion of mostly fasting urine samples reduces the potential impact of food and beverage consumption on urinary fluoride concentrations. Second, we were limited in our ability to examine patterns of associations of fluoride exposure with neurobehavior according to trimester

because only a subsample of participants had urine available for fluoride analyses in the first trimester and most participants did not fast prior to urine collection. Nevertheless, associations of first trimester MUF_{5G} with CBCL scores after adjusting for blood lead were in the same direction as for the third trimester. Third, we did not have data on tap water consumption habits for the study sample; however, home cooking rates were high, and rice tended to be a dietary staple among MADRES participants, which can be a source of tap water fluoride exposure. Fourth, given that the study sample resided in Los Angeles, California, and was predominately Hispanic, we do not know whether findings observed in this study are generalizable to other US populations or are nationally representative. Fifth, this study excluded participants who delivered their babies prior to 30 weeks' gestation which precluded examination of associations of MUF_{5G} with neurobehavior among children who were born very preterm. Sixth, lead concentrations in whole blood were only measured for most of the study sample during the first trimester, and therefore we were only able to adjust for first trimester blood lead in our third trimester analyses. Still, we do not anticipate confounding of associations of MUF_{5G} with CBCL scores by blood lead given that the inclusion of first trimester blood lead in first and third trimester models increased the magnitude of the associations. Furthermore, blood lead has been shown to be stable between the first and third trimesters of pregnancy,⁵⁰ which supports the use of first trimester blood lead as a proxy for third trimester blood lead.

Conclusions

This cohort study found that prenatal fluoride exposure was associated with increased risk for neurobehavioral problems among children residing in the US. These findings suggest that there may be a need to establish recommendations for limiting exposure to fluoride from all sources during the prenatal period, a time when the developing brain is known to be especially vulnerable to injury from environmental insults.

ARTICLE INFORMATION

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Corresponding Author: Ashley J. Malin, PhD, Department of Epidemiology, College of Public Health and Health Professions, University of Florida, 2004 Mowry Rd, Gainesville, FL 32603 (ashleymalin@ufl.edu).

Author Affiliations: Department of Epidemiology, College of Public Health and Health Professions University of Florida, Gainesville (Malin); College of Medicine, University of Florida, Gainesville (Malin); Department of Population and Public Health Sciences, Keck School of Medicine of University of Southern California, Los Angeles (Eckel, Hu, Hernandez-Castro, Yang, Farzan, Habre, Breton, Bastain); Department of Dental Public Health and Dental Informatics, School of Dentistry, Indiana University, Indianapolis (Martinez-Mier).

Author Contributions: Dr Malin and Ms Yang had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Malin, Eckel, Hu, Martinez-Mier, Bastain.

Critical review of the manuscript for important intellectual content: All authors.

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Supervision: Hu, Martinez-Mier, Farzan, Habre, Bastain.

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SUPPLEMENT 1.

eFigure 1. Participant Selection Flowchart for the Current Study Sample

eMethods.

eFigure 2. Directed Acyclic Graph (DAG) for Covariate Selection

eTable 1. Maternal Demographics According to Fluoride Sample

eFigure 3. Distributions of Raw Scores for CBCL Syndrome Scales Among Children in the MADRES Study at Age 3; n = 229

eFigure 4. Distributions of Raw Scores for CBCL DSM-Oriented Scales Among Children in the MADRES Study at Age 3; n = 229

eTable 2. CBCL Scores at Age 36-Months in the MADRES Cohort

eTable 3. Poisson Regression Estimating the Risk Ratio for Third Trimester MUFsg in Relation to CBCL Clinical Index Scores

eTable 4. Sensitivity Analysis Including "Borderline Clinical" with "Non-Clinical" Group as the Reference in Logistic Regression of Trimester 3 MUFsg With CBCL Clinical Index Scores

eTable 5. Sensitivity Analysis of Associations of MUFsg in Trimester 1 With CBCL Clinical Index Scores

eTable 6. Sensitivity Analysis of Associations of Trimester 1 MUFsg With Composite T-Scores, and Syndrome or DSM Scale Raw CBCL Scores at Age 3

eTable 7. Associations of MUFsg in Trimester 1 with CBCL Scores Adjusting for Blood Lead

eTable 8. Associations of MUFsg in Trimester 3 With CBCL Scores Adjusting for Trimester 1 Blood Lead

eTable 9. Associations of MUFsg in Trimester 3 with CBCL Clinical Index Scores Adjusting for Trimester 1 Blood Lead

eTable 10. Associations of MUFsg in Trimester 3 with CBCL Scores Among Women Who Fasted for ≥ 8 Hours

eTable 11. Trimester 3 MUFsg in Relation to CBCL Clinical Index Scores Among Women who Fasted for ≥ 8 Hours

eTable 12. Associations of MUFsg in Trimester 3 with CBCL Scores Including Women Who Smoked During Pregnancy

eTable 13. Trimester 3 MUFsg in Relation to CBCL Clinical Index Scores Including Women Who Smoked During Pregnancy

eTable 14. Associations of Average MUFsg Across Trimesters 1 and 3 With CBCL Scores

eTable 15. Average MUFsg Across Trimesters 1 and 3 in Relation to CBCL Clinical Index Scores

SUPPLEMENT 2.

Data Sharing Statement

Mission:

To protect, promote and improve the health of all people in Florida through integrated state, county, and community efforts.



Ron DeSantis
Governor

Joseph A. Ladapo, MD, PhD
State Surgeon General

Vision: To be the **Healthiest State** in the Nation

Guidance for Community Water Fluoridation

November 22, 2024

Tallahassee, Fla. – State Surgeon General Dr. Joseph A. Ladapo recommends against community water fluoridation due to the neuropsychiatric risk associated with fluoride exposure.

Fluoride is a naturally occurring ion present in groundwater, fresh and salt water, rainwater, soil, plants, and foods. Community water [fluoridation](#) is the process of adjusting the amount of fluoride in drinking water to the level recommended to prevent tooth decay. Historically, community water fluoridation was considered to be a method to systemically, through ingestion, deliver fluoride to all community members. However, currently many municipalities across the U.S. and several European countries, including Austria, Belgium, France, Germany, Italy, Norway, and Sweden, have [eliminated water fluoridation](#).

Today, fluoride is widely available from multiple sources, including topical fluorides, such as toothpaste, mouthwashes, and fluoride applications by dental providers. Evidence shows fluoride strengthens teeth, making them more decay resistant. However, additional research is being conducted to review the impacts of overall fluoride exposure in the population.

Several studies have reviewed fluoride exposure in vulnerable populations:

- A Mexico City, Mexico, study published in 2017 found that prenatal fluoride exposure was associated with [lower IQ](#) in both boys and girls ages six to twelve. Similarly, a nationwide Canadian study found that higher maternal urinary fluoride in pregnancy was associated with [reduced IQ](#) in boys ages three to four. The fluoride exposure levels in these studies are [comparable](#) to those found in pregnant women in the United States.
- A Canadian cross-sectional study published in 2019 found an association between exposure to fluoridated water and [attention deficit hyperactivity disorder \(ADHD\)](#) among children and adolescents between the ages of six and seventeen.
- Similarly, higher prenatal fluoride exposure was associated with increased incidence [of ADHD](#) in children ages six through twelve in a subgroup of the Mexico City, Mexico study.
- A 2023 Canadian study found that maternal exposure to fluoridated drinking water at 0.7 milligrams per liter throughout pregnancy was associated with [decreased child inhibitory control and cognitive flexibility](#), particularly in girls.
- Another study published in JAMA Network Open in May 2024, found higher [prenatal fluoride exposure](#) was associated with increased child neurobehavioral problems in Los Angeles, California. The authors recommended establishing guidelines for limiting fluoride exposure during pregnancy.
- On August 22, 2024, the U.S. Department of Health and Human Services National Toxicology Program (NTP) published a [report](#) evaluating total fluoride exposure from all sources.



- The report highlights a concern that some [pregnant women and children](#) may be receiving more fluoride than necessary due to fluoride exposure from multiple sources, including treated public water, water-added foods and beverages, teas, toothpaste, floss, and mouthwash. Thus, the combined total intake of fluoride may exceed safe amounts.
 - The report states that the majority of the 72 epidemiological studies pertaining to fluoride's impacts on children's IQ, published through April 2021, found an association between higher levels of fluoride consumption and reduced IQ in children.
 - While there is insufficient data to determine if the lower level of 0.7 milligrams per liter, currently recommended for U.S. community water systems, has a negative impact on children's IQ, the report concludes that there is moderate confidence in the scientific evidence that points to an association between higher levels of fluoride consumption and lower IQ in children.¹
- On September 24, 2024, [a U.S. District Court ruled](#) that community water fluoridation at 0.7 milligrams per liter presents an unreasonable risk of injury to health under the [Amended Toxic Substances Control Act \(Amended TSCA\)](#) and the U.S. Environmental Protection Agency is obliged to take regulatory action in response.

Other studies point to various potential impacts associated with systemic fluoride consumption that should be considered when weighing the risks and benefits of adding fluoride to community water systems, including increased risks of developing [sleep apnea](#), accumulation of fluoride in the pineal gland, [sleep cycle disturbance](#), [premature menarche](#) in adolescent girls, negative impacts on the [thyroid gland](#), and elevated occurrences of [skeletal fluorosis](#).

Due to the neuropsychiatric risk associated with fluoride exposure, particularly in pregnant women and children, and the wide availability of alternative sources of fluoride for dental health, the State Surgeon General recommends against community water fluoridation.

The Florida Department of Health strongly supports oral and overall health through:

- Operation and expansion of school-based preventive dental services.
- County health department dental clinics, which provide dental services to communities.
- Screening and treatment referral in pre-school and school settings.
- Provider education, including training on oral health service delivery for those with special health care needs.
- Promotion of healthy habits, with emphasis on a reduction in sugar consumption, through oral health education to communities.
- Providing oral health care supplies to community partners.
- Providing tobacco and vaping cessation resources and services.

Based on self-reported data from 2023, it is estimated that more than 70% of Floridians on community water systems receive fluoridated water. To see if your community water system is included, please visit the webpage [Public Water Systems Actively Fluoridating](#).

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Fluoride Exposure and Children's IQ Scores

A Systematic Review and Meta-Analysis

Kyla W. Taylor, PhD; Sorina E. Eftim, PhD; Christopher A. Sibrizzi, MPH; Robyn B. Blain, PhD; Kristen Magnuson, MESM; Pamela A. Hartman, MEM; Andrew A. Rooney, PhD; John R. Bucher, PhD

IMPORTANCE Previous meta-analyses suggest that fluoride exposure is adversely associated with children's IQ scores. An individual's total fluoride exposure comes primarily from fluoride in drinking water, food, and beverages.

OBJECTIVE To perform a systematic review and meta-analysis of epidemiological studies investigating children's IQ scores and prenatal or postnatal fluoride exposure.

DATA SOURCES BIOSIS, Embase, PsycInfo, PubMed, Scopus, Web of Science, CNKI, and Wanfang, searched through October 2023.

STUDY SELECTION Studies reporting children's IQ scores, fluoride exposure, and effect sizes.

DATA EXTRACTION AND SYNTHESIS Data were extracted into the Health Assessment Workplace Collaborative system. Study quality was evaluated using the OHAT risk-of-bias tool. Pooled standardized mean differences (SMDs) and regression coefficients were estimated with random-effects models.

MAIN OUTCOMES AND MEASURES Children's IQ scores.

RESULTS Of 74 studies included (64 cross-sectional and 10 cohort studies), most were conducted in China (n = 45); other locations included Canada (n = 3), Denmark (n = 1), India (n = 12), Iran (n = 4), Mexico (n = 4), New Zealand (n = 1), Pakistan (n = 2), Spain (n = 1), and Taiwan (n = 1). Fifty-two studies were rated high risk of bias and 22 were rated low risk of bias. Sixty-four studies reported inverse associations between fluoride exposure measures and children's IQ. Analysis of 59 studies with group-level measures of fluoride in drinking water, dental fluorosis, or other measures of fluoride exposure (47 high risk of bias, 12 low risk of bias; n = 20 932 children) showed an inverse association between fluoride exposure and IQ (pooled SMD, -0.45; 95% CI, -0.57 to -0.33; $P < .001$). In 31 studies reporting fluoride measured in drinking water, a dose-response association was found between exposed and reference groups (SMD, -0.15; 95% CI, -0.20 to -0.11; $P < .001$), and associations remained inverse when exposed groups were restricted to less than 4 mg/L and less than 2 mg/L; however, the association was null at less than 1.5 mg/L. In analyses restricted to low risk-of-bias studies, the association remained inverse when exposure was restricted to less than 4 mg/L, less than 2 mg/L, and less than 1.5 mg/L fluoride in drinking water. In 20 studies reporting fluoride measured in urine, there was an inverse dose-response association (SMD, -0.15; 95% CI, -0.23 to -0.07; $P < .001$). Associations remained inverse when exposed groups were restricted to less than 4 mg/L, less than 2 mg/L, and less than 1.5 mg/L fluoride in urine; the associations held in analyses restricted to the low risk-of-bias studies. Analysis of 13 studies with individual-level measures found an IQ score decrease of 1.63 points (95% CI, -2.33 to -0.93; $P < .001$) per 1-mg/L increase in urinary fluoride. Among low risk-of-bias studies, there was an IQ score decrease of 1.14 points (95% CI, -1.68 to -0.61; $P < .001$). Associations remained inverse when stratified by risk of bias, sex, age, outcome assessment type, country, exposure timing, and exposure matrix.

CONCLUSIONS AND RELEVANCE This systematic review and meta-analysis found inverse associations and a dose-response association between fluoride measurements in urine and drinking water and children's IQ across the large multicountry epidemiological literature. There were limited data and uncertainty in the dose-response association between fluoride exposure and children's IQ when fluoride exposure was estimated by drinking water alone at concentrations less than 1.5 mg/L. These findings may inform future comprehensive public health risk-benefit assessments of fluoride exposures.

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+ Supplemental content

Author Affiliations: Division of Translational Toxicology, National Institute of Environmental Health Sciences, National Institutes of Health, Research Triangle Park, North Carolina (Taylor, Rooney, Bucher); ICF, Reston, Virginia (Eftim, Sibrizzi, Blain, Magnuson, Hartman).

Corresponding Author: Kyla W. Taylor, PhD, Division of Translational Toxicology, National Institute of Environmental Health Sciences, National Institutes of Health, 530 Davis Dr, Morrisville, NC 27719 (kyla.taylor@nih.gov).

Fluoride from natural sources occurs in some community water systems (CWSs), and in the United States and some other countries, fluoride is added to public drinking water systems or salt for the prevention of tooth decay. For CWSs that add fluoride, the US Public Health Service recommends a fluoride concentration of 0.7 mg/L, the US Environmental Protection Agency's (EPA's) enforceable and nonenforceable standards for fluoride in drinking water are 4.0 mg/L and 2.0 mg/L,¹ and the World Health Organization's (WHO's) drinking water quality guideline for fluoride is 1.5 mg/L.² Water and water-based beverages are the main source of systemic fluoride intake. In the United States, the Centers for Disease Control and Prevention (CDC) estimates that water and processed beverages (eg, soda and juices) provide approximately 75% of a person's fluoride intake,³ and EPA estimates that 40% to 70% of a person's fluoride intake comes from fluoridated drinking water.⁴ However, an individual's total exposure also reflects contributions from fluoride in other sources, such as food, dental products, industrial emissions, and pharmaceuticals.⁴ Accumulating evidence suggests that fluoride exposure may affect brain development. A 2006 report from the National Research Council (NRC) concluded that high levels of naturally occurring fluoride in drinking water may be of concern for neurotoxic effects.⁵ This finding was largely based on studies from endemic fluorosis areas in China that had limitations in study design or methods. Following the NRC review, studies from an additional 10 countries have been published (eFigure 1A in Supplement 1). Previous meta-analyses⁶⁻⁸ found an inverse association between fluoride exposure and children's IQ. Since the most recent meta-analysis,⁸ 4 new studies on exposure to fluoride and children's IQ have been published, including 3 studies⁹⁻¹¹ that measured individual-level maternal and children's urinary fluoride concentrations.

To incorporate newer evidence and increase transparency, objectivity, and rigor in the analysis of fluoride research, we conducted a systematic review and meta-analysis of studies that provided estimates of group-level and individual-level fluoride exposure in relation to children's IQ scores.

Methods

The search, selection, extraction, and risk-of-bias evaluation of studies were part of a larger systematic review.¹² Brief methods are outlined herein, with detailed methods available in the protocol¹³ and the "Detailed Methods" section of eAppendix 1 in Supplement 1. This study follows the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) reporting guidelines. Data analysis was conducted from June 2020 to January 2024. The most recent analysis update was performed in January and February 2024.

Systematic Literature Review, Study Selection, and Data Extraction

Literature searches were conducted in BIOSIS, Embase, PsycInfo, PubMed, Scopus, Web of Science, CNKI, and Wanfang. The searches were performed through October 2023 without language restrictions.¹³ Studies were independently

Key Points

Question Is fluoride exposure associated with children's IQ scores?

Findings Despite differences in exposure and outcome measures and risk of bias across studies, and when using group-level and individual-level exposure estimates, this systematic review and meta-analysis of 74 cross-sectional and prospective cohort studies found significant inverse associations between fluoride exposure and children's IQ scores. For fluoride measured in water, associations remained inverse when exposed groups were restricted to less than 4 mg/L or less than 2 mg/L but not when restricted to less than 1.5 mg/L; for fluoride measured in urine, associations remained inverse at less than 4 mg/L, less than 2 mg/L, and less than 1.5 mg/L; and among the subset of low risk-of-bias studies, there were inverse associations when exposed groups were restricted to less than 4 mg/L, less than 2 mg/L, and less than 1.5 mg/L for analyses of fluoride measured both in water and in urine.

Meaning This comprehensive meta-analysis may inform future risk-benefit assessments of the use of fluoride in children's oral health.

screened by 2 reviewers against inclusion and exclusion criteria described in the "Detailed Methods" section of eAppendix 1 in Supplement 1 and the protocol.¹³ Data were extracted from included studies by 1 extractor and verified by a second extractor into the Health Assessment Workspace Collaborative (HAWC) system. Data are publicly available and downloadable (<https://hawcproject.org/assessment/405/>).

Quality Assessment: Risk of Bias

Quality of individual studies, also called risk of bias, was independently evaluated by 2 trained assessors following criteria prespecified in the protocol,¹³ using the National Toxicology Program's or Division of Translational Toxicology's OHAT approach.¹⁴ Risk-of-bias questions concerning confounding, exposure characterization, and outcome assessment were considered key. If not addressed appropriately, these questions were thought to have the greatest potential impact on the results.¹³ The remaining risk-of-bias questions were used to identify other concerns that may indicate serious risk-of-bias issues (eg, selection bias, inappropriate statistical analysis). No study was excluded from the meta-analysis based on concerns for risk of bias; however, subgroup analyses were conducted with and without high risk-of-bias studies (ie, studies rated probably high risk of bias for ≥ 2 key risk-of-bias questions or definitely high risk of bias for any single question) to assess their potential impact, in terms of magnitude and direction of bias, on the results. Ratings and justification are available in HAWC (<https://hawcproject.org/assessment/405/>).

Statistical Analysis

We conducted the following analyses, planned a priori in the protocol: (1) mean-effects meta-analysis, (2) dose-response mean-effects meta-analysis, and (3) regression slopes meta-analysis (detailed methods are provided in the "Detailed Methods" section of eAppendix 1 in Supplement 1).

The mean-effects meta-analysis included studies that reported mean IQ scores and group-level exposures for at least 1 exposed group and 1 reference group. The effect estimates were

standardized mean differences (SMDs) for heteroscedastic population variances.¹⁵⁻¹⁷ SMDs were calculated from the difference in mean IQ scores between an exposed group and a reference group. If an individual study reported mean IQ scores for multiple exposure groups, the highest exposure group was considered the exposed group and the lowest exposure group was considered the reference group. A sensitivity analysis was performed to evaluate the impact of all exposure groups combined compared with a reference group. Pooled SMDs and 95% CIs were estimated using random-effects models. To determine whether the data support an exposure-response association, we conducted a dose-response mean-effects meta-analysis that included studies from the mean-effects meta-analysis and used a 1-step approach as described in the protocol.^{13,18-20} A pooled dose-response curve was estimated using a restricted maximum likelihood estimation method. Potential nonlinear associations were examined using quadratic terms and restricted cubic splines. Model comparison was based on the maximum likelihood Akaike information criterion (AIC).²¹ To examine associations at lower fluoride levels, subgroup analyses were restricted to 0 to less than 4 mg/L (comparable to EPA's enforceable drinking water standard for fluoride of ≤ 4 mg/L), 0 to less than 2 mg/L (comparable to EPA's nonenforceable standard for fluoride in drinking water of ≤ 2 mg/L), and 0 to less than 1.5 mg/L (comparable to WHO's guideline for fluoride in drinking water of ≤ 1.5 mg/L).⁴

The regression slopes meta-analysis included studies that reported regression slopes to estimate associations between individual-level fluoride exposures and children's IQ. Data from individual studies were pooled using a random-effects model.²²

Heterogeneity was assessed by Cochran *Q* test²³ and the I^2 statistic.²⁴ Subgroup analyses stratified studies by risk of bias (high or low), study location (country), outcome assessment, exposure matrix (eg, urine, water), sex, and age to further investigate sources of heterogeneity. An analysis stratified by prenatal or postnatal exposure was suggested post hoc. Potential publication bias was assessed with funnel plots and Egger tests.²⁵⁻²⁷ If publication bias was present, trim-and-fill methods^{28,29} were used to estimate the number of hypothetical "missing" studies and predict the impact of the missing studies on the pooled effect estimate.

Statistical analyses were performed using Stata version 17.0 statistical software (StataCorp LLC).³⁰ The combine, meta esize, meta set, meta summarize, drmeta, meta funnel, meta bias, meta trimfill, and metareg packages were used.³¹

Results

Study Sample

A total of 74 publications (64 cross-sectional studies and 10 prospective cohort studies) met the inclusion criteria, with 65 included in the primary analyses and an additional 9 included in sensitivity analyses (eFigure 1B in Supplement 1; see eTable 2 in Supplement 1 for excluded publications). Characteristics of the 74 publications and the study-specific effect estimates used in the meta-analyses are shown in eTable 1 in Supplement 1. Most studies were conducted in China ($n = 45$); other locations

included Canada ($n = 3$), Denmark ($n = 1$), India ($n = 12$), Iran ($n = 4$), Mexico ($n = 4$), New Zealand ($n = 1$), Pakistan ($n = 2$), Spain ($n = 1$), and Taiwan ($n = 1$). No studies were conducted in the United States. Of these, 59 publications reported mean IQ scores for group-level exposures^{10,11,32-95} and 19 reported regression slopes for individual-level exposures based on urinary or water fluoride concentrations and fluoride intake.^{9-11,32-38,96-104} Additional details on study characteristics are provided in the "Results" section of eAppendix 1 in Supplement 1. Sixty-four studies reported inverse associations between fluoride exposure measures and children's IQ. Fifty-two studies were rated high risk of bias. Twenty-two studies were rated low risk of bias, with 13 rated low risk of bias across all 7 risk-of-bias domains and 9 rated low risk of bias in 6 domains and probably high risk of bias in no more than 1 domain. Results from risk-of-bias evaluations are presented in eFigure 2 in Supplement 1. Interactive versions of the figures and risk-of-bias evaluations are available in HAWC (links provided in the "Results" section of eAppendix 1 in Supplement 1). Further details and justification about low risk-of-bias studies are presented in eAppendix 2 in Supplement 1.

Mean-Effects Meta-Analysis

The meta-analysis of 59 studies (47 high risk of bias, 12 low risk of bias; $n = 20\,932$ children) that provided mean IQ scores showed that, when compared with children exposed to lower fluoride levels, children exposed to higher fluoride levels had statistically significantly lower IQ scores (random-effects pooled SMD, -0.45 ; 95% CI, -0.57 to -0.33 ; $P < .001$) (Table 1 and Figure 1). There was evidence of high heterogeneity ($I^2 = 94\%$; $P < .001$; Table 1) and publication bias (funnel plot and Egger $P < .001$, Begg $P = .03$; eFigures 3 and 4 in Supplement 1). Adjusting for possible publication bias through trim-and-fill analysis supported the statistically significant inverse association after imputation of 2 additional studies to the right side (adjusted SMD, -0.39 ; 95% CI, -0.58 to -0.20) or 17 studies to the left side (adjusted SMD, -0.63 ; 95% CI, -0.76 to -0.50) (eFigures 5 and 6 in Supplement 1). Fifty-two of the 59 studies (88%) reported an inverse association with SMDs ranging from -5.34 (95% CI, -6.34 to -4.34) to -0.04 (95% CI, -0.45 to 0.36) (Figure 1). Seven studies that did not report inverse associations reported SMDs ranging from 0.00 (95% CI, -0.25 to 0.25) to 0.43 (95% CI, 0.07 to 0.80).^{10,32,37,42,47-50} Three studies⁴³⁻⁴⁵ lacked clear descriptions of their intelligence assessment methods; however, sensitivity analyses did not reveal substantial changes in the pooled SMD estimate when these studies were excluded or when a study¹⁰³ that reported the cognitive subset of evaluations using Bayley and McCarthy tests was included (eTable 3 in Supplement 1).

Among the low risk-of-bias studies,^{10,11,32-35,37,42,47-50} the random-effects pooled SMD was -0.19 (95% CI, -0.35 to -0.04 ; $P = .01$) with high heterogeneity ($I^2 = 87\%$) (Table 1; eFigure 7 in Supplement 1) and no evidence of publication bias (funnel plot and Egger $P = .56$; eFigures 8 and 9 in Supplement 1). Among the high risk-of-bias studies, the random-effects pooled SMD was -0.52 (95% CI, -0.68 to -0.37 ; $P < .001$) with high heterogeneity ($I^2 = 94\%$) (Table 1; eFigure 7 in Supplement 1). There was evidence of publication bias (funnel plot and Egger

$P < .001$; eFigures 8 and 9 in Supplement 1); the trim-and-fill analysis had an adjusted pooled SMD of -0.47 (95% CI, -0.72 to -0.23) (eFigures 10 and 11 in Supplement 1).

Subgroup analyses by sex, age, study location, outcome assessment type, and exposure assessment matrix found inverse associations between measures of fluoride exposure and children's IQ (Table 1; eFigures 12-16 in Supplement 1). The subgroup analyses did not explain a large amount of the overall heterogeneity; however, the degree of heterogeneity was lower for studies restricted to Iran ($I^2 = 57\%$), children aged 10 years or older ($I^2 = 71\%$), and girls ($I^2 = 78\%$) ("Results" section of eAppendix 1 in Supplement 1). The results of the meta-regression models indicate that year of publication and mean age of children did not explain a large degree of heterogeneity ("Results" section of eAppendix 1 in Supplement 1).

Dose-Response Mean-Effects Meta-Analysis

The dose-response mean-effects meta-analysis included data from 38 studies (eTable 1 in Supplement 1). We excluded studies for which there was evidence that coexposures to arsenic or iodine might be differential.^{36,41,44,51-54,105} Results from both the analysis of 31 studies with group-level fluoride measurements in drinking water (24 high risk of bias, 7 low risk of bias; $n = 12\,487$ children) and the analysis of 20 studies with group-level mean urinary fluoride levels (10 high risk of bias, 10 low risk of bias; $n = 9756$ children) found that lower children's IQ scores were associated with increasing levels of fluoride exposure. Based on the linear models, the mean SMD between exposed and reference groups was -0.15 (95% CI, -0.20 to -0.11 ; $P < .001$) for water fluoride levels and -0.15 (95% CI, -0.23 to -0.07 ; $P < .001$) for urinary fluoride levels (Table 2; eTable 4 in Supplement 1). Based on the AIC, the best model fit was achieved when restricted cubic spline levels were added to the linear models for drinking water. Given the small difference in AICs between the different models, and considerations of parsimony and ease of interpretability, the linear model results were chosen for the purposes of discussion and are presented in Table 2, although results from all models are presented in eTable 4 in Supplement 1. For fluoride in water, the associations remained inverse when exposed groups were restricted to less than 4 mg/L (16 high risk-of-bias studies, 7 low risk-of-bias studies) or less than 2 mg/L (4 high risk-of-bias studies, 4 low risk-of-bias studies); however, the association was null at less than 1.5 mg/L (4 high risk-of-bias studies, 3 low risk-of-bias studies) (Table 2; eTable 4 in Supplement 1). When we included only studies with low risk of bias, the associations remained inverse at less than 4 mg/L, less than 2 mg/L, and less than 1.5 mg/L fluoride in water, and the linear model was the best fit (Table 2; eTable 4 in Supplement 1). For urinary fluoride, the associations remained inverse when exposed groups were restricted to less than 4 mg/L (4 high risk-of-bias studies, 10 low risk-of-bias studies), less than 2 mg/L (2 high risk-of-bias studies, 4 low risk-of-bias studies), and less than 1.5 mg/L (1 high risk-of-bias study, 4 low risk-of-bias studies). When we included only the low risk-of-bias studies, the associations remained inverse at less than 4 mg/L, less than 2 mg/L, and less than 1.5 mg/L for urinary fluoride, and the linear model was the best fit (Table 2; eTable 4 in Supplement 1).

Table 1. Pooled Standardized Mean Differences (SMDs) From Random-Effects Meta-Analyses of the Association Between Group-Level Measures of Fluoride Exposure and IQ Scores in Children

Analysis	Studies, No.	SMD (95% CI)	Heterogeneity	
			P value	I^2 , %
Overall association with IQ	59	-0.45 (-0.57 to -0.33)	<.001	94
Subgroup analysis				
Risk of bias				
Low	12	-0.19 (-0.35 to -0.04)	.01	87
High	47	-0.52 (-0.68 to -0.37)	<.001	94
Sex				
Female	15	-0.45 (-0.65 to -0.25)	<.001	78
Male	16	-0.53 (-0.77 to -0.29)	<.001	88
Age, y				
<10 ^a	14	-0.38 (-0.57 to -0.19)	<.001	82
≥10	17	-0.52 (-0.67 to -0.37)	<.001	71
Country				
China	41	-0.42 (-0.51 to -0.33)	<.001	86
India	8	-1.09 (-2.23 to 0.06)	<.001	98
Iran	4	-0.68 (-0.99 to -0.38)	.08	57
Canada	2	0.01 (-0.14 to 0.16)	NA	0
Pakistan	2	0.10 (-0.57 to 0.77)	.01	83
New Zealand	1	0.01 (-0.19 to 0.22)	NA	NA
Taiwan	1	0.10 (-0.10 to 0.29)	NA	NA
Assessment type				
CRT-RC	31	-0.35 (-0.45 to -0.25)	<.001	85
Non-CRT-RC tests	28	-0.59 (-0.88 to -0.29)	<.001	96
Raven tests	12	-0.72 (-1.48 to 0.04)	<.001	99
Other tests	16	-0.52 (-0.72 to -0.32)	<.001	87
Exposure matrix				
Water fluoride	34	-0.35 (-0.45 to -0.24)	<.001	87
Dental fluorosis	9	-0.86 (-1.91 to 0.19)	.11	99
Other exposures ^b	16	-0.54 (-0.71 to -0.37)	<.001	81

Abbreviations: CRT-RC, Combined Raven Test-The Rural Edition in China; NA, not applicable.

^a Both An et al⁵⁵ and Li et al⁵⁶ included 10-year-old children in the group listed as younger than 10 years (ages 7-10 years reported).

^b Includes iodine,^{44,52-54,57,58} arsenic,^{36,51,59} aluminum,⁶⁰ and non-drinking water fluoride (ie, fluoride from coal burning⁶¹⁻⁶⁹).

Regression Slopes Meta-Analysis

Each of the 19 studies with individual-level fluoride measures (2 high risk-of-bias studies, 17 low risk-of-bias studies) (eTable 1 in Supplement 1) reported urinary fluoride levels,^{9-11,32-38,96-104} 2 reported fluoride intake,^{32,97} and 2 reported water fluoride levels.^{32,33} Thirteen studies were included in the primary regression slopes meta-analysis. The 6 remaining studies, including 3 studies⁹⁶⁻⁹⁸ with populations that overlapped with already-included studies^{32,33,101} and 3 that

Figure 1. Forest Plot for Random-Effects Meta-Analysis of Standardized Mean Differences (SMDs) of the Association Between Group-Level Measures of Fluoride Exposure and IQ Scores in Children

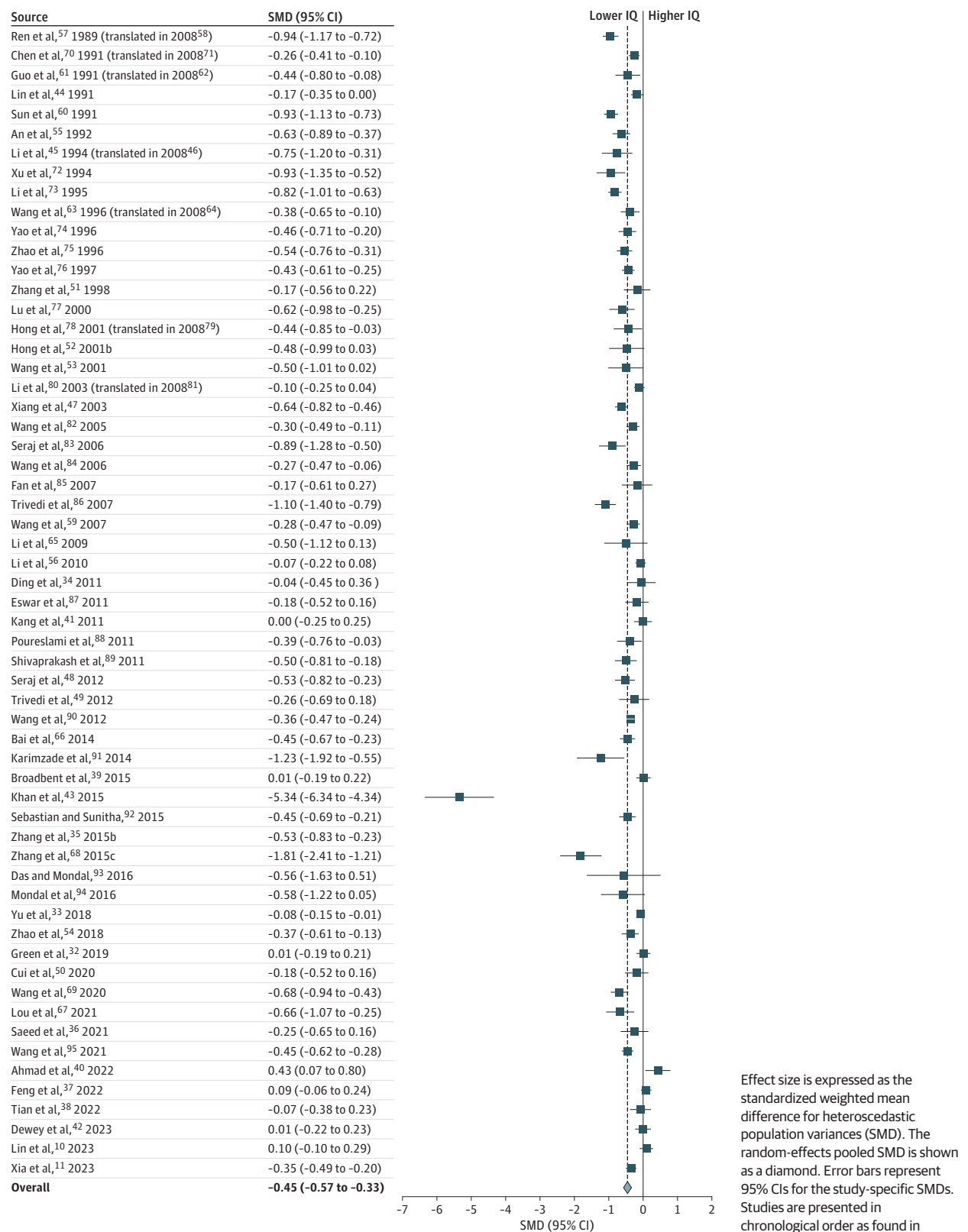


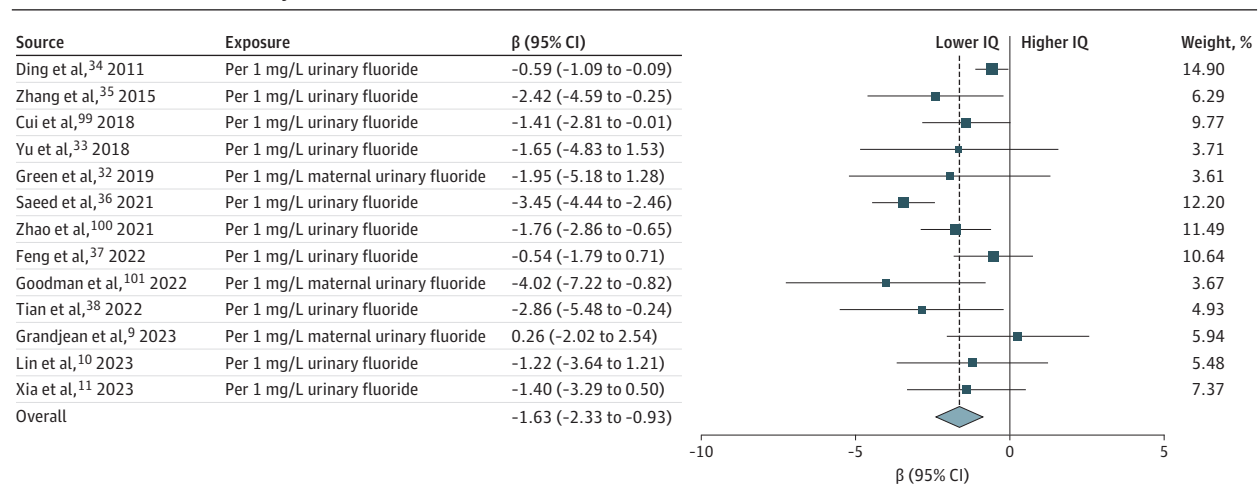
Table 2. Pooled Changes in Standardized Mean Differences (SMDs) From the Linear Model From the Dose-Response Mean-Effects Meta-Analyses Using Group-Level Measures of Fluoride Exposure

Fluoride exposure, mg/L	Studies, No.	Effect estimates, No. ^a	Children, No.	Parameter estimates ^b	
				β (95% CI)	P value
Water fluoride, all studies					
All data	31	41	12 487	-0.15 (-0.20 to -0.11)	<.001
<4	23	29	9554	-0.22 (-0.27 to -0.17)	<.001
<2	8	10	3682	-0.18 (-0.40 to 0.03)	.10
<1.5	7	7	2832	0.05 (-0.36 to 0.45)	.82
Water fluoride, low risk-of-bias studies					
All data	7	12	5066	-0.21 (-0.33 to -0.09)	.001
<4	7	10	4962	-0.23 (-0.34 to -0.11)	<.001
<2	4	5	1632	-0.33 (-0.53 to -0.13)	.001
<1.5	3	3	879	-0.32 (-0.91 to 0.26)	.28
Urinary fluoride, all studies					
All data	20	32	9756	-0.15 (-0.23 to -0.07)	<.001
<4	14	25	8019	-0.20 (-0.31 to -0.08)	.001
<2	6	10	4692	-0.08 (-0.15 to -0.005)	.04
<1.5	5	8	4219	-0.08 (-0.15 to -0.003)	.04
Urinary fluoride, low risk-of-bias studies					
All data	10	14	6847	-0.13 (-0.23 to -0.03)	.01
<4	10	14	6847	-0.13 (-0.23 to -0.03)	.01
<2	4	7	4179	-0.08 (-0.15 to -0.002)	.04
<1.5	4	7	4179	-0.08 (-0.15 to -0.002)	.04

^a This represents the number of effect estimates (SMDs) from all the studies included in the analysis. Studies with more than 2 exposure levels provided more than 1 SMD for inclusion in the dose-response meta-analysis.

^b Parameter estimates are changes in SMDs (β [95% CI]) for the linear model based on the restricted maximum likelihood models.

Figure 2. Forest Plot for Random-Effects Meta-Analysis of Regression Slopes of the Association Between Individual-Level Urinary Fluoride Measures and IQ Scores in Children



The effect measures are regression slopes (β) per 1-mg/L increase in urinary fluoride. The βs for individual studies are shown with boxes representing the weight, and the pooled estimate is shown as a diamond. Error bars represent

95% CIs for the study-specific βs. Studies are presented in chronological order as found in eTable 1 in Supplement 1.

reported scores based on Bayley assessments,¹⁰²⁻¹⁰⁴ were included in sensitivity analyses (eTable 5 in Supplement 1).

In the primary regression slopes meta-analysis, the pooled effect estimate from the 13 studies (2 high risk-of-bias studies, 11 low risk-of-bias studies; n = 4475 children) with individual-level data showed that a 1-mg/L increase in urinary fluoride was associated with a statistically significant decrease in IQ score of 1.63 points (95% CI, -2.33 to -0.93; P < .001) (Figure 2) with evidence of heterogeneity (I² = 60%;

P < .001; Table 3) and no indications of publication bias (eFigures 17 and 18 in Supplement 1). When restricted to low risk-of-bias studies, the decrease in IQ score was 1.14 points (95% CI, -1.68 to -0.61; P < .001) with evidence of low heterogeneity (I² = 23%; P = .28; Table 3; eFigure 19 in Supplement 1) and a slight indication of publication bias (eFigure 20 in Supplement 1). The trim-and-fill analysis had an adjusted estimate of -0.78 (95% CI, -1.33 to -0.22) (eFigures 21 and 22 in Supplement 1).

Table 3. Pooled Changes in IQ Scores From Random-Effects Meta-Analyses of the Association Between Individual-Level Measures of Urinary Fluoride and IQ Scores in Children

Analysis	Studies, No.	β (95% CI)	Heterogeneity	
			P value	I^2 , %
Overall association with IQ	13	-1.63 (-2.33 to -0.93)	<.001	60
Subgroup analysis				
Risk of bias				
Low	11	-1.14 (-1.68 to -0.61)	.28	23
High	2	-3.38 (-4.30 to -2.45)	.68	0
Sex				
Female	3	-1.07 (-2.20 to 0.05)	.33	0
Male	3	-1.21 (-3.80 to 1.37)	.09	65
Country				
Canada	1	-1.95 (-5.19 to 1.28)	NA	NA
China	8	-1.20 (-1.79 to -0.61)	.25	31
Denmark	1	0.26 (-2.02 to 2.54)	NA	NA
Mexico	1	-4.02 (-7.22 to -0.82)	NA	NA
Pakistan	1	-3.45 (-4.44 to -2.46)	NA	NA
Taiwan	1	-1.22 (-3.64 to 1.21)	NA	NA
Assessment type				
CRT-RC	9	-1.19 (-1.75 to -0.63)	.34	27
Non-CRT-RC tests	4	-2.32 (-4.26 to -0.37)	.03	66
Exposure matrix				
Urinary fluoride	13	-1.63 (-2.33 to -0.93)	<.001	60
Intake	2	-3.87 (-7.15 to -0.59)	.74	0
Water fluoride	2	-4.77 (-9.09 to -0.45)	.71	0
Exposure timing				
Prenatal	3	-1.70 (-4.23 to 0.84)	.09	57
Postnatal	10	-1.65 (-2.39 to -0.90)	<.001	64

Abbreviations: CRT-RC, Combined Raven Test-The Rural Edition in China; NA, not applicable.

Subgroup analyses by risk of bias, sex, country, exposure matrix, outcome assessment type, and prenatal or postnatal exposure found inverse associations between measures of fluoride exposure and children's IQ (Table 3; eFigures 23-27 in Supplement 1). The sensitivity analyses including reporting scores based on Bayley assessments¹⁰²⁻¹⁰⁴ showed no substantial changes in the pooled effect estimates (eTable 5 in Supplement 1).

Discussion

This systematic review and meta-analysis found statistically significant inverse associations between measures of fluoride exposure and children's IQ. These inverse associations were observed in all 3 sets of meta-analyses: the mean-effects meta-analysis (47 high risk-of-bias studies, 12 low risk-of-bias studies) and dose-response mean-effects meta-analysis (27 high risk-of-bias studies, 11 low risk-of-bias studies) of group-level fluoride exposure, and the regression slopes meta-analysis (2 high risk-of-bias studies, 11 low risk-of-bias

studies) of individual-level urinary fluoride. Within each of these meta-analyses, we used prespecified criteria to assess study quality and classify studies into low and high risk of bias. Stratified analyses found similar inverse associations in both study quality strata. Further subgroup analyses by sex, age, timing of exposure, study location, outcome assessment type, and exposure assessment matrix also found inverse associations between fluoride exposure and children's IQ.

Studies in these meta-analyses included cross-sectional and prospective cohort designs, each study having its own strengths and limitations. Although all studies contribute to our understanding of the overall association, well-designed studies that accurately measure exposure and outcome and adequately account for potential confounding variables are particularly informative. In these meta-analyses, we followed the OHAT approach¹⁴ to extract data from each of the published studies and to classify studies into high risk of bias and low risk of bias based on carefully predefined criteria.¹³ To make our process and decisions transparent, we provide full public access to the extracted data, risk-of-bias ratings, and rationale for those ratings for each individual study. These data can be used by other investigators to evaluate or extend our process and analysis (<https://hawcproject.org/assessment/405/>).

Studies using group-level exposures were assessed in the mean-effects meta-analysis. An advantage of such studies is that they can, for example, examine communities with different CWS fluoride levels. Although in the United States 40% to 70% of a person's fluoride intake comes from fluoridated drinking water, there are other sources of fluoride exposure.⁴ Therefore, relying on CWS levels alone may underestimate an individual's total fluoride exposure, which may vary considerably among members of a group depending on individual behaviors. Most of the studies in the mean-effects meta-analysis were cross-sectional; however, we have higher confidence in cross-sectional studies when there is evidence of temporality.¹⁴ Among the low risk-of-bias cross-sectional studies, most provided information to establish that exposure likely preceded the outcome (eg, only including children who had lived in a community since birth or children who had dental fluorosis).

Studies using individual-level exposures were assessed in the regression slopes meta-analysis, which included 13 studies with urinary fluoride measures, a more precise exposure assessment measure than group-level exposures. Unlike drinking water levels, individual-level urinary fluoride concentrations include all ingested fluoride and are considered a valid estimate of total fluoride exposure.^{106,107} Fluoride in urine is measured from both single or spot samples and multiple collections. When compared with 24-hour urine samples, spot samples are more prone to the influence of timing of exposure and can be affected by differences in dilution. However, correlations between urinary fluoride concentrations from 24-hour samples and spot samples adjusted for urinary dilution have been described.¹⁰⁸ There were several recent North American prospective cohort studies conducted in Canada and Mexico^{32,96,97,101} that reported maternal urinary fluoride levels comparable to those in the United States.^{109,110} These studies

combined multiple urinary measurements over the course of pregnancy to examine prenatal fluoride exposure during a critical period of brain development. Although the estimated decreases in IQ found in the regression slopes meta-analysis may seem small (1.63 IQ points per 1-mg/L increase in urinary fluoride), research on other neurotoxicants has shown that subtle shifts in IQ at the population level can affect people who fall within the high and low ranges of the population's IQ distribution.¹¹¹⁻¹¹⁵ For context, a 5-point decrease in a population's IQ would nearly double the number of people classified as intellectually disabled.¹¹⁶

Finally, studies with group-level exposure measurements were used in the dose-response mean-effects meta-analysis of water or urinary fluoride levels. Although we examined 2 nonlinear models, a linear model almost always provided the best fit for both water and urinary data. There was a statistically significant dose-response association between group-level fluoride measures and children's IQ. In stratified analyses of low risk-of-bias studies, the association remained inverse when exposure was restricted to less than 4 mg/L, less than 2 mg/L, and less than 1.5 mg/L fluoride in water or urine; except for fluoride concentrations less than 1.5 mg/L in water, these results were statistically significant. There was some inconsistency in the best-fit model and a lack of statistical significance at lower levels for water fluoride exposures, leading to uncertainty in the shape of the dose-response curve. This uncertainty is not surprising given the lower number of observations for fluoride concentrations in water ($n = 879$ from 3 studies) compared with urinary fluoride concentrations ($n = 4218$ from 5 studies). The ability to detect a true effect is reduced at lower exposure levels when exposure contrasts are diminished.¹¹⁷ Although the same cutoffs were used for the water and urine subgroup analyses, fluoride levels in water likely underestimate total fluoride exposures that are better estimated by levels in urine. Variable fluoride exposures from nonwater sources may also decrease the precision of the effect estimates at lower fluoride concentrations in water. In contrast, the best model fit for urinary fluoride concentrations was consistently linear.

Elevated naturally occurring fluoride levels in groundwater (>1.5 mg/L) are prevalent globally and include central Australia, eastern Brazil, sub-Saharan Africa, the southern Arabian Peninsula, south and east Asia, and western North America.¹¹⁸ Although to our knowledge no epidemiological studies addressing fluoride exposure and children's IQ have been conducted in the United States, significant inequalities in CWS fluoride levels exist by county sociodemographic characteristics, including racial and ethnic composition, especially among Hispanic and Latino communities.¹¹⁹ Of note, there are regions of the United States where CWS and private wells contain natural fluoride concentrations greater than 1.5 mg/L,¹²⁰ serving more than 2.9 million US residents.¹¹⁹ In addition, the US Geological Survey estimates that 172 000 US residents are served by domestic wells that exceed EPA's enforceable standard of 4.0 mg/L fluoride in drinking water, and 522 000 are served by domestic wells that exceed EPA's non-enforceable standard of 2.0 mg/L fluoride in drinking water.¹ To reduce risk of moderate-to-severe dental fluorosis, the CDC

recommends that parents use an alternative source of water for children aged 8 years or younger and for bottle-fed infants if their primary drinking water contains greater than 2 mg/L of fluoride.¹²¹ Currently, there are no recommendations or restrictions on fluoride levels in drinking water based on cognitive neurodevelopmental outcomes.¹²¹

To our knowledge, no studies of fluoride exposure and children's IQ have been performed in the United States, and no nationally representative urinary fluoride levels are available, hindering application of these findings to the US population. Although this meta-analysis was not designed to address the broader public health implications of water fluoridation in the United States, these results may inform future public health risk-benefit assessments of fluoride.

Strengths and Limitations

Strengths of this systematic review and meta-analysis include a large body of literature, a predefined systematic search and screening process, risk-of-bias assessment of individual studies, prespecified subgroup analyses, and use of both group-level and individual-level exposure data. The consistency of the inverse associations across the high and low risk-of-bias studies, different intelligence assessment methods, different exposure matrices, different study locations, different analytical approaches, and evidence of a dose-response association strengthen confidence in the conclusion of an overall inverse association between fluoride exposure and children's IQ. It is notable that there is a diversity of study design factors across studies, which could be described as overall heterogeneity of the body of evidence. In this case, the heterogeneity supports the robustness of the conclusions and is different from heterogeneity in the results, which we did not find in this meta-analysis.

The body of existing literature has limitations in that many of the studies were classified as having high risk of bias. Most of the studies included in the mean-effects and dose-response mean-effects meta-analyses were cross-sectional and had study design and/or methodological limitations. However, the consistency in meta-analytic associations across the high and low risk-of-bias studies and the other subgroup analyses reduced the likelihood that specific biases or potential confounders in individual studies could explain the inverse association between fluoride exposure and children's IQ.

While several recent studies conclude that fluoride exposures from community water fluoridation are not associated with children's IQ or other neurodevelopmental outcomes,¹²²⁻¹²⁴ the results of the mean-effects meta-analysis were consistent with 6 previous meta-analyses^{6-8,122,125,126} that reported statistically significant inverse associations between fluoride exposure and children's IQ scores (see the "Characteristics of Previous Meta-Analyses" section of eAppendix 1 and eTable 6 in Supplement 1).

Conclusions

This meta-analysis found inverse associations and an inverse dose-response association between fluoride exposure and children's IQ across the multicountry epidemiological literature.

There were limited data and uncertainty in the dose-response association between fluoride exposure and children's IQ when fluoride exposure was estimated by drinking water alone at concentrations less than 1.5 mg/L. Confidence in the associations

at lower fluoride levels could be increased by additional prospective cohort studies with individual fluoride exposure measures. These results may inform future comprehensive public health risk-benefit assessments of fluoride.

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Concept and design: Taylor, Eftim, Blain, Hartman, Rooney, Bucher.

Acquisition, analysis, or interpretation of data:

Taylor, Eftim, Sibrizzi, Blain, Magnuson, Hartman, Bucher.

Drafting of the manuscript: Taylor, Eftim, Magnuson, Rooney, Bucher.

Critical review of the manuscript for important intellectual content: Taylor, Eftim, Sibrizzi, Blain, Hartman, Rooney, Bucher.

Statistical analysis: Eftim.

Obtained funding: Rooney, Bucher.

Administrative, technical, or material support: Sibrizzi, Blain, Magnuson, Hartman, Rooney, Bucher.

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“Excellence in electrical distribution design since 1981”

SENT BY EMAIL

April 3, 2025

Mount Horeb Utilities
Jordan Schmitz, Superintendent
138 E. Main Street
Mount Horeb, WI 53572

Subject: Mount Horeb Utilities, Multiple-Year Underground Electric Facility Installation
Unit Pricing Contract, M25-21F, Spec 4217

Dear Jordan:

We have analyzed and reviewed the bids received for the Mount Horeb Utilities, Multiple-Year Underground Electric Facility Installation Unit Pricing Contract. Five contractors submitted bids on this project. The contractors were J&R Underground, LLC., Corevac, LLC., Holtger Bros., INC., Intercon Construction, INC., and Michels Underground Cable, INC.,

To determine the lowest responsible bidder, we analyzed the bids based on units for potential projects that Mount Horeb Utilities **could** construct. The bid documents clearly state that the owner makes no guarantee of any work to the contractor that is awarded this contract. When Mount Horeb Utilities has a project that they intend to construct using this pricing, a Task Order between the utility and awarded bidder will be created clearly detailing what units will be used, the quantity for each unit, and the total cost of the Task Order.

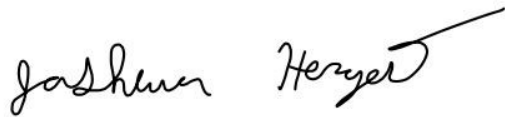
After our analysis, we have determined that J&R Underground, LLC., is the evaluated low bidder and recommend that you award contract M25-21F, Spec. 4217, to them. J&R Underground has worked successfully with many other municipal electric utilities in southcentral Wisconsin. They are excellent contractors with experienced crews that do exceptional work.

Please note that there will not be an 'official' contract amount as the contract price will not be established until Task Order(s) are created for the project(s) that will be constructed.

If you have any questions, please let me know. Once Mount Horeb Utilities has approved this contractor, please let us know and we will begin to send the contract out for signatures.

Sincerely,

FORSTER ELECTRICAL ENGINEERING, INC.

A handwritten signature in black ink that reads "Joshua M. Hergert". The signature is written in a cursive style with a long, sweeping horizontal line extending from the end of the name.

Joshua M. Hergert

Copy: Bruce Beth, P.E., Frank Westphal, Paige Younggren



Stoughton Utilities
 Task Order Unit Total
 Total Units for North Rd. Boring
 Latest update: 4.3.2025

Unit Description	Qty	UOM	Corevac		J&R Underground		Michels		Intercon		Holtger bros.	
			Unit	Extended	Unit	Extended	Unit	Extended	Unit	Extended	Unit	Extended
Directional bore: (1) 2" Conduit (Conduit by Owner)	8,490	Lineal Foot	\$ 13.43	\$ 114,020.70	\$ 13.00	\$ 110,370.00	\$ 14.98	\$ 127,180.20	\$ 14.00	\$ 118,860.00	\$ 16.00	\$ 135,840.00
Directional bore: (1) 3" Conduit (Conduit by Owner)	171	Lineal Foot	\$ 15.64	\$ 2,674.44	\$ 17.00	\$ 2,907.00	\$ 18.72	\$ 3,201.12	\$ 16.00	\$ 2,736.00	\$ 18.00	\$ 3,078.00
Add (1) 2" Conduit to Bore	15,690	Lineal Foot	\$ 4.20	\$ 65,898.00	\$ 2.00	\$ 31,380.00	\$ 2.28	\$ 35,773.20	\$ 6.00	\$ 94,140.00	\$ 1.30	\$ 20,397.00
Add (1) 3" Conduit to Bore	204	Lineal Foot	\$ 4.92	\$ 1,003.68	\$ 4.50	\$ 918.00	\$ 7.99	\$ 1,629.96	\$ 8.00	\$ 1,632.00	\$ 2.20	\$ 448.80
Adder for Boring through Partial Rock	1,848	Lineal Foot	\$ 22.57	\$ 41,709.36	\$ 8.00	\$ 14,784.00	\$ 50.85	\$ 93,970.80	\$ 35.00	\$ 64,680.00	\$ 48.00	\$ 88,704.00
Single Task Order mobilization & demobilization for Bore Crew(s)	1	each	\$ 2,142.00	\$ 2,142.00	\$ 500.00	\$ 500.00	\$ 449.37	\$ 449.37	\$ 390.00	\$ 390.00	\$ 850.00	\$ 850.00
					\$ 227,448.18	\$ 160,859.00	\$ 262,204.65	\$ 282,438.00		\$ 249,317.80		



We are Publicly Owned and Operated

Mount Horeb Utilities

Jordan Schmitz
Electric Superintendent
301 Blue Mounds. Mt. Horeb, WI 53572
(608) 437-3300 or (608) 437-3084

Electric: March 2025

- 3 New Underground Services
- 4 Outages (1- Wind, 2- Animal, 1- Customer)
- Crew just finished meter testing for the winter.
- Crew has been getting ready to help the Public Service crew with installing new lighting at Grundahl Park.
- Crew began GIS inspections for underground facilities this spring.
- Utility had our annual safety training at the shop along with audiograms.
- I have been super busy taking in new projects coming to the village this year yet.
- I was happy with how the outages were this last month as it seemed like we had over 20 mph winds constantly!



We are Publicly Owned and Operated

Mount Horeb Water Utility

Brian Schult

Water Superintendent

301 Blue Mounds St. Mt. Horeb, WI 53572

(608) 437-9431 or (608) 437-3084

Direct (608) 437-9431

Cell # (608) 636-5763

In the month of March, I am still getting familiarized with the water system, scada system, wells and everything else.

Jordy has been helping out with the computer related question

We have had quite a few high-water related reports to follow up with customers.

We got our normal sampling done for the month, which consisted of 8 bacti samples 1 fluoride sample.

We started testing residential water meters this month, we swapped and tested 92 water meters. We need to test about 400 residential meters this year so we got a good start.

Bryan Moyer, Jeromy Martin, Shane Kahl and myself went to WRWA conference in Green Bay from March 25th – March 28th.

We had competent person, excavation training and CPR training this month.

We had no call outs for wells/scada related issues in the month of March.

Thank You,

Brian Schult



Mount Horeb Wastewater

Monthly Report for March 2025

Submitted 04/02/2025

Plant is running well; we are operating below all permitted limits.

All staff completed their annual audiograms, staff also attended the annual safety training provided by Fehr Graham; topics included excavation/trench safety, PPE, confined space entry. Staff also completed the CPR/AED training provided by MHFD.

We hosted students from the high school's AP Environmental Studies; the students got a tour of the facility including an overview of the treatment process, collections system, as well as our lab operations.

Staff assisted the water department by hydro-excavating with our Vactor to help locate a main leak.

We were able to clean 3,210 feet of sanitary main, inspect 12 manholes, and televise 3,673 feet of sanitary main, in the process there were some areas of concern identified. We will pursue repairs for the highest priority areas as add-ons to the water main and street repair projects.

Our CIP proposal for sanitary main lining and manhole rehab was approved and submitted. We will be in touch with a project manager from Visu-Sewer soon to coordinate the work to be completed this summer; we intend to use social media and our website to inform the public ahead of time.

We also got confirmation from the contractor selected to complete the prairie install as part of our adaptive management program. The proposal includes seed planting, as well as one year maintenance package.



Monthly Wastewater Utility Operations Report

March 2025

Submitted to the Utility Commission 04/04/2025

Monthly average influent flow: 476,000 gpd Design average flow: 790,000 gpd

Biological Oxygen Demand (5 day)

BOD5 Influent: **288.3 mg/l** mo. average Daily maximum: **342 mg/l**

Effluent: **3.3 mg/l** mo. average Daily maximum: **5.0 mg/l**

Permit limit: 22 mg/l mo. average Times exceeded **0**

Effluent mo. average lbs/day: **13.0**

Permit limit: 112 lbs/day monthly average Times exceeded **0**

Total Suspended Solids

TSS- Influent: **407.8 mg/l** mo. average Daily maximum: **630 mg/l**

Effluent: **7.2 mg/l** mo. average Daily maximum: **21.4 mg/l**

Permit limit: 22 mg/l mo. average Times exceeded **0**

Effluent mo. average lb/day: **31.9**

Permit limit: 112 lbs/day mo. average Times exceeded **0**

Ammonia Nitrogen- Effluent monthly average: **<.08 mg/l**

Permit limit: 4 mg/l monthly average Times exceeded **0**

Total Phosphorus- Effluent monthly average: **.22 mg/l**

Permit limit: 1.0 mg/l monthly average Times exceeded **0**

Chloride- Effluent weekly average: **409.5 mg/l** (4 consecutive samples for the week)

Permit limit: 625 mg/l weekly average Times exceeded **0**

Dissolved Oxygen- Effluent daily minimum: **9.65 mg/l**

Permit limit: 6 mg/l daily minimum Times exceeded **0**

Effluent Temperature deg F Daily Max: **51.9** Daily Min: **48.2**