ORIGINAL ARTICLE

Association of Water, Sanitation, and Hygiene-related Factors, Nutritional Status, and Sociodemographic Covariates with Urinary Iodine Concentration Levels among Filipino Women of Reproductive Age (15-49 Years): A Cross-sectional Study

Vanessa Joy A. Timoteo-Garcia, RCh, MSc, PhD,[1] Carlos Bernard K. Jacinto, MHS,[2]
Kim Leonard G. dela Luna, RND, MSPH, PhD,[1] Ma. Clara R. Cabaluna, RMT,[1]
Denniese C. Sy, RND, MSPH,[1] Chanz Joshua G. Acebuche, RND,[1]
Raycha Lei Concess M. Rama-Sabandal, RMT, MPH[1] and Rowel C. Malimban, RMT, MPH[1]

[1]*Department of Nutrition, College of Public Health, University of the Philippines Manila*
[2]*Department of Epidemiology and Biostatistics, College of Public Health, University of the Philippines Manila*

ABSTRACT

Background and Objective. Iodine deficiency (ID) remains a public health concern in the Philippines. While the country has made progress in addressing ID, pockets of deficiency persist in specific population groups, such as the Filipino women of reproductive age (WRA), whose nutritional status is critical in supporting their own health and that of their children. It has been previously shown that factors related to water, sanitation, and hygiene (WASH) are potentially associated with ID. Thus, this study was conducted to determine the association of WASH-related variables with the levels of urinary iodine concentration (UIC), the primary indicator of recent iodine intake and iodine nutrition status, among Filipino WRA.

Methods. A cross-sectional secondary analysis of nationally representative survey data was employed in this study. The data of 12,344 Filipino women aged 15-49 years old from the 2018, 2019, and 2021 Expanded National Nutrition Surveys (ENNS) were utilized and analyzed. Multiple linear regression analyses were performed to identify WASH-related factors, nutritional status, and sociodemographic covariates as predictors of UIC levels in WRA of ENNS while holding other variables constant. Adjusted regression coefficients were reported. Survey weights were not applied in the analyses as the focus of the study was on determining associations and effect estimates.

Results. Several factors were identified to be significantly associated with insufficient UIC status among the Filipino WRA, including late reproductive years, being married or having a partner, low wealth quintiles, no formal education or completion of elementary level, level 1 source of drinking water, no water treatment modalities, or the absence of an existing garbage disposal method. Upon fully adjusting for age groups, nutritional status, ethnicity, and socioeconomic status as covariates in the

eISSN 2094-9278 (Online)
Published: June 15, 2026
https://doi.org/10.47895/amp.vi0.13963

Corresponding author:
Vanessa Joy A. Timoteo-Garcia, RCh, MSc, PhD
Department of Nutrition
College of Public Health
University of the Philippines Manila
625 Pedro Gil Street, Ermita, Manila 1000, Philippines
Email: vatimoteo@up.edu.ph
ORCiD: https://orcid.org/0000-0002-5827-8510

models, level 3 drinking water (adjusted effects = 14.02 μg/L; 95% CI: 6.28, 21.77; p <0.001), garbage disposal by a collector system (adjusted effects = 10.81 μg/L; 95% CI: 1.18, 20.44; p = 0.028), and household salt iodine concentration in ppm (adjusted effects = 0.96 μg/L; 95% CI: 0.79, 1.14; p <0.001) were significantly associated with increased UIC levels in WRA. Conversely, the use of bottled water (adjusted effects = -14.54 μg/L; 95% CI: -26.06, -3.01; p = 0.013) was associated with lower UIC levels.

Conclusion. This study revealed that WASH-related factors influence UIC levels of Filipino WRA, including improved water access and the method of garbage disposal. Nutritional status, age, ethnicity, household wealth index, dwelling type, occupation, and household salt iodine content were also observed as significant factors. Hence, targeted WASH interventions, alongside salt iodization programs, should be prioritized to comprehensively address iodine deficiency among Filipino WRA.

Keywords: iodine deficiency, Water, Sanitation, and Hygiene (WASH), urinary iodine concentration, women of reproductive age

INTRODUCTION

Iodine deficiency (ID) remains a public health issue in the Philippines despite sustained efforts to improve the iodine status of the general population.[1] Over the years, iodine status in the country has been improved through the Act for Salt Iodization Nationwide (ASIN Law) or Republic Act 8172, which mandated the iodization of all food-grade salt for consumption.[2,3] However, the most recent data of the Expanded National Nutrition Survey (ENNS) showed that pockets of ID still persist in certain population groups and regions in the country.[1] Vulnerable groups such as children, pregnant or lactating women, and women of reproductive age (WRA) continue to be affected.[4-6]

WRA are particularly at risk of iodine deficiency due to increased physiological demands, especially during pregnancy and lactation.[7] Maintaining sufficient iodine levels before and during pregnancy is critical to ensure optimal maternal and infant health outcomes.[8] Adequate iodine intake from food sources (*i.e.,* seafood, dairy products, and eggs) during these periods can prevent the impairment of thyroid function for the mother and ameliorate negative fetal effects that may lead to severe outcomes such as irreversible brain damage, intellectual impairment, and developmental delays, among others.[9] Therefore, early diagnosis and application of effective interventions for improving iodine status are crucial.

It is essential to underscore the importance of having adequate urinary iodine concentration (UIC), a well-validated biomarker that reflects the iodine status of the population, in assessing and identifying at-risk groups.[10] A median UIC lower than 100 ug/L is commonly used to clinically define ID, whereas a median UIC greater than 300 ug/L is already classified as excessive and may also lead to adverse health consequences.[1] Although UIC is not considered a useful tool at the individual level due to high daily variability, monitoring median UIC in the WRA group will provide insights into iodine levels, as UIC directly correlates with recent dietary iodine consumption.[7] This will help guide public health strategies aimed at preventing ID and the associated spectrum of iodine deficiency disorders (IDD) that include goiter and hypothyroidism.[7,8]

While ensuring adequate iodine intake from dietary sources and monitoring UIC levels are critical in addressing ID, it should be noted that several non-dietary factors may influence the iodine status of an individual, including environmental and behavioral elements such as water source, sanitation, and hygiene practices (WASH).[11] Emerging evidence suggests that poor WASH conditions may influence or compromise the intake, utilization, and bioavailability of iodine in several ways. First, poor sanitation and inadequate hygiene practices can increase exposure to enteric pathogens that lead to diarrheal diseases and parasitic infections, which potentially impair the proper absorption of iodine in the body.[8,11] Chronic gastrointestinal infections can cause intestinal inflammation and reduced iodine absorption efficiency even when dietary iodine is adequate. Second, WASH conditions may also potentially affect the iodine content of household salt through the preservation pathway. Water treatment with chlorine and contamination of water sources, along with the improper packaging and storage of iodized salt, may similarly contribute to iodine loss, further exacerbating deficiencies.[7,12] Third, poor waste management and inadequate sanitation infrastructure potentially lead to environmental conditions that increase overall infectious disease burden, indirectly affecting nutritional status through multiple mechanisms that include nutrient losses and increased metabolic demands. These mechanisms are not mutually exclusive. WASH-related factors may be associated with UIC levels, potentially through their influence on the efficiency of iodine absorption and retention, independent of dietary intakes.

There were studies, however, that present contradictory findings with regard to the role of safe and sufficient WASH-related factors on the improvement of iodine status. A cross-sectional study done among Sri Lankan children aged 12-59 months reported no significant association between UIE levels and different types of drinking water, although ID was found to be low in children who had consumed filtered water as compared to those who had used unmodified, boiled, or chlorinated water.[13] In addition, there has been a scarcity of data that specifically link WASH-related factors with iodine status in Southeast Asia, a region reported to have noticeable differences in terms of access to clean water, lack of adequate sanitation facilities, and vulnerabilities to water-related public health issues.[14] To date, no locally conducted epidemiological study has presented direct evidence of the association of WASH-related factors with the iodine status among the vulnerable groups, such as the Filipino WRA. It was hypothesized that improved WASH conditions are positively associated with higher UIC levels among Filipino WRA, potentially through mechanisms affecting iodine absorption and bioavailability.

Thus, this study aimed to determine the association of WASH-related factors with the UIC levels of women of reproductive age in the Philippines using a population-based national nutrition survey data. Addressing WASH-related concerns is deemed equally important as improving dietary iodine intakes in ensuring adequate iodine levels, particularly among vulnerable population groups. The study findings will provide valuable insights into how WASH may influence iodine status, which will then help inform and guide stakeholders in designing more effective interventions that will improve iodine nutrition status in the country.

MATERIALS AND METHODS

Study Design

This study utilized secondary data collected from the 2018-2019 and 2021 Expanded National Nutrition Surveys (ENNS) that were conducted by the Department of Science and Technology-Food and Nutrition Research Institute (DOST-FNRI).[1,15] The ENNS followed a cross-sectional study design.[1,15] Secondary data from ENNS were chosen because it allows the simultaneous assessment of exposure (*i.e.,* WASH practices) and outcome (*i.e.,* UIC levels) within a defined population at a specific point in time. This is particularly suitable for measuring associations among exposures and health-related outcomes in large population groups, making it efficient and cost-effective for the objective of this research.[16] Additionally, data from the 2018-2019 and 2021 ENNS cycles were pooled and analyzed as a single cross-sectional dataset. All surveys employed standardized protocols that ensured comparability across participants and consistency in measurement methods across the years.[1,15]

Sampling Design and Study Participants

The ENNS employed the 2013 Master Sample (MS) of the Philippine Statistics Authority for its sampling design, which followed a two-stage cluster sampling method.[17] Here, *barangays* or groups of adjacent small *barangays* served as the primary sampling units (PSU) while households were selected as the secondary sampling units.[1,15] The 2013 MS covered 117 sampling domains that consisted of 81 provinces, 33 highly urbanized cities, and three other areas, with about 100 to 400 households per PSU.[17] Sixteen independent sample replicates were utilized to ensure precise estimates at the provincial or city level, with around 12 to 16 households sampled per PSU on average. Details on the objectives, design, and methods of the ENNS have been reported elsewhere.[18]

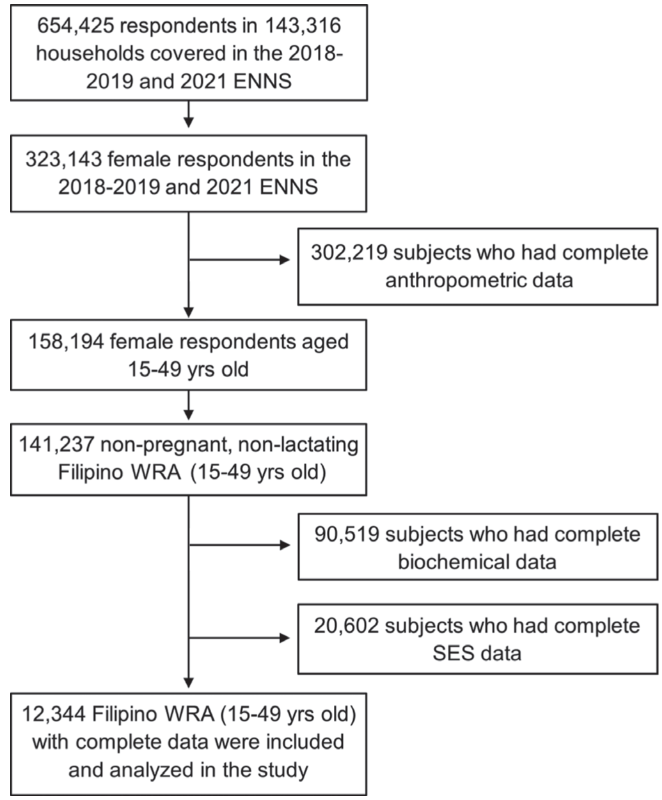

Figure 1. Flowchart illustrating the selection process of study participants.

Participants included in the study are Filipino women of reproductive age who were 15 to 49 years old at the time of the surveys. Pregnant or lactating women were excluded as their physiological status may lead to inaccurate estimates of normal iodine status, thus, potentially confounding the results. From the starting 654,425 individuals covered in the 2018-2019 and 2021 ENNS, 141,237 subjects were non-pregnant and non-lactating Filipino WRA. Complete-case analysis was employed, whereby only participants with complete data on the following survey components: anthropometric survey, biochemical survey, and socioeconomic status survey, were included in the analyses. Non-completion may have resulted from refusal, logistical constraints during data collection, or other factors. This may introduce potential selection bias if the data were not missing completely at random.

A final sample size of 12,344 Filipino WRA met all eligibility criteria and was analyzed in this study (Figure 1). As the study is a secondary analysis of ENNS data, the sample size was predetermined by the available dataset and no *a priori* power calculation was conducted.

Data Collection and Processing

Secondary data from the four survey components of the 2018-2019 and 2021 ENNS were processed and analyzed in the study, namely (1) anthropometry, (2) biochemical, (3) socioeconomic individual-level, and (4) socioeconomic household-level components.[1,15] These are available online and free to download at the eNutrition website of the DOST-FNRI (https://enutrition.fnri.dost.gov.ph/home.php (accessed on May 2025)).[19]

Calibration of Research Equipment and Tools

As documented in the Facts and Figures, all equipment and instruments utilized during fieldwork surveys of the 2018-2019 and 2021 ENNS were calibrated following national metrology standards set by the Department of Science and Technology-Industrial Technology Development Institute.[1,15]

Orientation of the Participants about the Data Collection Procedure

The 2018-2019 and 2021 ENNS methodology reported that duly signed written informed consents were collected from the participants at the start of data collection to ensure their voluntary involvement in the study. The informed consent forms clearly explained the purpose of the ENNS, the nature of the data being gathered, the procedures for data collection, and assurances of confidentiality to safeguard the personal information of respondents. Participation was ensured to be completely voluntary, with respondents retaining the option to withdraw at any point in the survey.[1,15]

Measurement of Urinary Iodine Concentration Levels and Assessment of Iodine Nutrition Status

The 2018-2019 and 2021 ENNS reported that non-fasting urine samples were collected from Filipino WRA respondents in participating households. Approximately 15 mL of midstream urine sample was collected into a sterile plastic cup before transfer to polystyrene bottles, which were kept in freezers or ice chests with dry ice while in the field and in transit to the DOST-FNRI Biochemical Laboratory.[1,15] Samples were then kept at -80°C freezers until further processing.

Levels of UIC were determined following the ammonium persulfate digestion method.[20] To ensure precision of the said analytical method, a pool of urine samples with pre-determined UIC levels was analyzed along with the collected survey samples.[6] To assess accuracy, on the other hand, Seronorm Trace Elements Urine was used as a certified reference material.[6,21] UIC measurement in the ENNS has been reported in detail previously.[1,6,15]

Assessment of iodine deficiency in the ENNS, as reported, was based on median urinary iodine (UI) levels.[1,15] The following epidemiological criteria set by the World Health Organization (WHO), United Nations Children's Fund, and International Council for the Control of Iodine Deficiency Disorders was then followed: <20 ug/L as severe iodine deficiency, 20-49 ug/L as moderate ID, 50-99 ug/L as mild ID, 100-199 ug/L as optimal, 200-299 µg/L as more than adequate, and >300 µg/L as excessive.[1,7,15]

Measurement of other Variables

Data from the sociodemographic and anthropometric surveys of the ENNS were collected as follows. This has been reported in detail previously.[1,15]

1. ***Demographic Characteristics and Socioeconomic Status Survey***. The sociodemographics of the participants were obtained via a structured face-to-face interview and an electronic data collection system that was facilitated by trained survey researchers.
   a. *Demographic characteristics.* Data on sex, age, educational attainment, employment status, occupation, and ethnicity were obtained under this component.[1,15]
   b. *Socioeconomic status (including household health and sanitation).* Information on civil status, wealth index, dwelling type, drinking water source, treatment of drinking water, source of cooking water, source of water for basic hygiene practice, type of toilet facility, ownership of toilet facility, method of garbage disposal, and practice of waste segregation were collected for each household under this component.[1,15]
2. ***Anthropometric Survey.*** Assessment of the height and weight of participants was similarly done by trained health professionals following standard procedures:
   a. *Height.* This was measured using a Seca™ microtoise and recorded to the nearest 0.1 cm. Measurements were taken twice. A third reading was taken if difference between measurements exceeded 0.5 cm.[1,15]
   b. *Weight.* A calibrated Detecto™ platform beam balance weighing scale was used to measure the weight of participants. Measurements were similarly done twice and recorded to the nearest 0.01 kilograms. Another reading was taken if the difference between the two values was higher than 0.3 kilogram.[1,15]
   c. *Body mass index.* BMI was calculated as the participant's weight in kilograms divided by the height in meters squared.[22] BMI was used to classify the nutritional status of participants.

Operational Definition of Research Variables

Table 1 presents the operational definitions of the variables used and analyzed in the study.

Data Processing and Statistical Analysis

All analyses in this study were carried out using the software STATA 14.[24] Descriptive statistics were generated for describing the characteristics of WRA participants, wherein categorical variables were expressed in counts and percentage values. Using chi-square test, UIC status was initially disaggregated according to different demographic profiles to describe how iodine status, categorized as adequate or insufficient UIC (≥100 ug/L or <100 ug/L, respectively), varied across groups (Table 1).

Table 1. Definition and Measurement of Study Variables

Variables	Operational Definition	Categories
Urinary Iodine Concentration †	Classification of participants' iodine status as measured from collected urine samples in a non-fasting state[7]	(1) Adequate: UIC ≥100 ug/L (2) Insufficient: UIC <100 ug/L
Age Categories of WRA	Classification group of WRA based on age	(1) Adolescents: 15-19 years old (2) Young women: 20-24 years old (3) Prime reproductive women: 25-34 years old (4) Late reproductive women: 35-49 years old
Nutritional Status	Classification of participant's BMI[22]	(1) Normal: BMI ≥18.5 kg/m^2 (2) Underweight: BMI <18.5 kg/m^2
Ethnicity	Refers to the classification of a participant based on self-identified ethnic or sociocultural grouping	(1) Not belonging to an ethnic group (2) Belonging to an ethnic group
Household Wealth Index	Measure of a household's socioeconomic status based on wealth quintiles[1,15]	(1) Poorest and poor (2) Middle (3) Rich and richest
Place of Residence	Classification of the place of residence	(1) Rural (2) Urban
Type of Dwelling Unit	Refers to the current living quarters of the participants at the time of the survey	(1) Residential: single house, duplex, multi-unit residential (2) Non-residential: commercial, industrial, agricultural, or institutional living quarters (3) Other dwelling/housing units
Source of Drinking Water	Classification of the main source of drinking water in a household at the time of the survey based on DENR AO 26-A[23]	(1) Level 1: Point source (2) Level 2: Communal faucet system or standposts (3) Level 3: Waterworks system or individual house connections
With Water Treatment	Refers to whether a household employs modalities of water treatment for safer drinking water	(1) Without (2) With
Type of Water Treatment Modalities	Classification of the type of method used for treating drinking water before consumption	(1) No treatment (2) Filtration and natural disinfection (3) Boiling (4) Use of bleach or chlorine (5) Use of bottled water
Type of Toilet Facility	Classification of the type of toilet facility used in a household	(1) No toilet facility at all (2) Sealed (3) Pit system
Garbage Disposal by Collector System	Refers to whether a household employed a collector system as a usual practice of garbage disposal	(1) No (2) Yes
Garbage Disposal by Burning	Refers to whether a household employs burning as a usual practice of garbage disposal	(1) No (2) Yes
Garbage Disposal by Compost Pit	Refers to whether a household used a compost pit for garbage disposal	(1) No (2) Yes
Garbage Disposal by Dumping/Throwing	Refers to whether a household follows dumping/ throwing for garbage disposal	(1) No (2) Yes
Garbage Segregation	Refers to whether a household employed garbage segregation during garbage disposal	(1) No (2) Yes

† UIC was treated as a categorical variable in descriptive analyses and as a continuous variable in regression analyses.

UIC in ug/L was treated as a continuous variable in the main analyses of the study. The distribution of UIC was initially assessed using histograms and Q-Q plots, which demonstrated an approximately normal distribution with no evident outliers warranting data transformation. Shapiro-Wilk test was additionally performed to test for normality. Associations of WASH-related factors with UIC levels were then analyzed through multiple linear regressions. Age groups, nutritional status, ethnicity, and socioeconomic status (*e.g.*, household wealth index) served as covariates and were fully adjusted for in the models. No subgroup analyses, tests for interactions, or sensitivity analyses were carried out.

The bases for utilizing untransformed UIC levels are as follows: (1) the large sample size (n = 12,344) provided robustness to violations of normality assumptions; (2) the regression coefficients in the original scale (μg/L) are more interpretable for public health applications than log-transformed values, allowing comparison with the WHO-recommended median UIC thresholds; and (3) this approach is consistent with previous epidemiological studies examining

UIC as a continuous outcome in identifying factors associated with iodine nutrition. A *p*-value threshold of 0.05 was used to determine statistical significance in the analyses.

Ethical Considerations

The secondary data utilized in this study were obtained from the DOST-FNRI's Public Use Files (PUFs). The study protocol was registered through the Research Grants Administration Office (RGAO) with reference number RGAO-2025-0136. Approval for the conduct of the ENNS was granted by the DOST-FNRI Institutional Ethics Review Committee (FIERC) with protocol number FIERC-2017-017. It was reported that all the work performed in the ENNS was in alignment with the Code of Ethics of the World Medical Association (Declaration of Helsinki). As such, informed consents have been secured from all participating households prior to their involvement in the ENNS, and all available data and information were treated with the utmost confidentiality.[1,15]

RESULTS

Characteristics of the Study Participants

Among the 12,344 WRA, more than half (51.98%) were aged 35-49 years old, which is classified as an advanced or late reproductive stage in women. This was followed by prime reproductive participants aged 25-34 years old, who were at the mid-reproductive (26.49%), and young women aged 20-24 years old, who were at early reproductive years (13.56%). The majority of the participants were married (70.93%) and did not belong to any ethnic or minority group (93.95%). In terms of household wealth quintile, nearly half were classified into the poorest and poor subgroup (42.77%), followed by the rich and richest subgroup (35.15%) (Table 2).

About half of the participants (48.3%) had completed high school, while 33.13% were able to finish college level or higher. In terms of current work status and occupation, most of the WRA had either no occupation or were identified as housekeeper, student, or pensioner (62.98%), while the remaining were employed or running a business. Of these, 24% were identified as skilled workers, 6.69% had elementary occupations, and 6.29% were professionals. Almost all of the participants (99.79%) lived in residential dwelling units, and the majority (90.98%) had normal nutritional status (Table 2).

Table 2. Demographic Profile and Nutritional Status of WRA in the Philippines, 2018-2019 and 2021 (n=12,344)

Demographic Profile and Nutritional Status	n	%
Age (years)		
Adolescents (15-19)	984	7.97
Young women (20-24)	1,674	13.56
Prime reproductive women (25-34)	3,270	26.49
Late reproductive women (35-49)	6,416	51.98
Nutritional Status		
Underweight	1,113	9.02
Normal	11,231	90.98
Civil Status		
Single	2,993	24.25
Partnered	8,756	70.93
Had partner	594	4.81
No response	1	0.01
Ethnicity		
Without ethnicity	11,597	93.95
With ethnicity	747	6.05
Household Wealth Index		
Poorest and poor	5,280	42.77
Middle	2,725	22.08
Rich and richest	4,339	35.15
Educational Attainment		
Not applicable	8	0.06
No grade completed	142	1.15
Elementary level	2,144	17.37
High school level	5,961	48.30
College level and above	4,089	33.13
Current Work		
No occupation	1,107	8.97
Housekeeper	4,962	40.20
Student	1,468	11.89
Pensioner	7	0.06
With a job/business	4,800	38.89
Present Occupation		
No occupation/Housekeeper/Student/Pensioner	7,774	62.98
Elementary occupations	826	6.69
Skilled agricultural, forestry, and fishery workers	339	2.75
Other skilled workers	2,629	21.3
Professionals	776	6.29
Type of Dwelling Unit		
Residential	12,318	99.79
Non-residential	11	0.09
Other dwelling/housing units	15	0.12

Disaggregation of Sociodemographic Covariates and WASH-related Factors by UIC Status among Filipino WRA

The age group of women with the highest insufficient UIC was aged 35-49 years (57.76%), followed by women aged 25-34 years (24.99%), then women aged 20-24 years (11.65%), and women aged 15-19 years (5.59%). A similar ranking of proportions was observed among participants with adequate UIC levels, with the 35-49 age group accounting for nearly half (49.73%) of these cases.

In terms of nutritional status, most participants with insufficient UIC (89.97%) had a normal BMI, while 10.03% were underweight. The same was seen among those with adequate UIC levels, with 91.33% classified as having normal nutritional status. Civil status also showed a similar distribution, where the majority of insufficient UIC cases were individuals who were married or with partners (74.06%), followed by single individuals (20.53%). Individuals with partners also made up the highest proportion of those with adequate UIC (69.72%) (Table 3).

Table 3. Disaggregation of Demographic Characteristics and WASH-related Factors by Urinary Iodine Concentration (UIC) Status among WRA in the Philippines, 2018-2019 and 2021

Variables	UIC Status, n (%)	
	Insufficient (<100 ug/L)	Adequate (≥100 ug/L)
Age (years)*		
Adolescents (15-19)	189 (5.59)	793 (8.88)
Young women (20-24)	394 (11.65)	1,279 (14.32)
Prime reproductive women (25-34)	845 (24.99)	2,417 (27.07)
Late reproductive women (35-49)	1,953 (57.76)	4,440 (49.73)
Nutritional Status		
Underweight	339 (10.03)	774 (8.67)
Normal	3,041 (89.97)	8,154 (91.33)
Civil Status*		
Single	694 (20.53)	2,294 (25.69)
Partnered	2,504 (74.06)	6,225 (69.72)
Had partner	183 (5.41)	409 (4.58)
No response	0 (0)	1 (0.01)
Ethnicity*		
Without ethnicity	3,108 (91.93)	8,460 (94.75)
With ethnicity	273 (8.07)	469 (5.25)
Household Wealth Index*		
Poorest and poor	1,663 (49.19)	3,600 (40.32)
Middle	694 (20.53)	2,026 (22.69)
Rich and richest	1,024 (30.29)	3,303 (36.99)
Educational Attainment*		
Not applicable	2 (0.06)	3 (0.03)
No grade completed	71 (2.10)	70 (0.78)
Elementary level	707 (20.91)	1,426 (15.98)
High school level	1,607 (47.53)	4,339 (48.61)
College level and above	994 (29.40)	3,088 (34.60)
Current Work*		
No occupation	325 (9.61)	782 (8.76)
Housekeeper	1,448 (42.83)	3,493 (39.12)
Student	296 (8.75)	1,170 (13.10)
Pensioner	0 (0)	7 (0.08)
With a job/business	1,312 (38.81)	3,477 (38.94)
Present Occupation*		
No occupation/Housekeeper/ Student/Pensioner	2,074 (62.79)	5,467 (63.03)
Elementary occupations	234 (7.08)	568 (6.55)
Skilled agricultural, forestry, and fishery workers	133 (4.03)	196 (2.26)
Other skilled workers	668 (20.22)	1,887 (21.75)
Professionals	194 (5.87)	556 (6.41)
Type of Dwelling Unit		
Residential	3,374 (99.79)	8,911 (99.80)
Non-residential	3 (0.09)	7 (0.08)
Other dwelling/housing units	4 (0.12)	11 (0.12)
Source of Drinking Water*		
Level 1 (point source)	1,335 (39.49)	2,758 (30.89)
Level 2 (communal faucet system or standposts)	231 (6.83)	571 (6.39)
Level 3 (waterworks system or individual house connections)	1,815 (53.68)	5,600 (62.72)
With Water Treatment*		
No	1,795 (72.23)	4,739 (74.21)
Yes	478 (19.24)	1,031 (16.14)
Not Applicable	212 (8.53)	616 (9.65)
Type of Water Treatment Modalities*		
No treatment	1,795 (72.23)	4,739 (74.21)
Filtration and natural disinfection	241 (9.70)	465 (7.28)
Boiling	225 (9.05)	545 (8.53)
Use of sterilizing agent	12 (0.48)	21 (0.33)
Use of bottled water	212 (8.53)	616 (9.65)
Type of Toilet Facility*		
No toilet facility at all	132 (3.97)	222 (2.51)
Sealed	3,168 (95.25)	8,568 (96.91)
Pit System	26 (0.78)	51 (0.58)
Garbage Disposal by Collector System*		
No	1,879 (55.58)	4,033 (45.17)
Yes	1,502 (44.24)	4,896 (54.83)
Garbage Disposal by Burning*		
No	2,005 (59.30)	5,868 (65.72)
Yes	1,376 (40.70)	3,061 (34.28)
Garbage Disposal by Compost Pit*		
No	2,487 (73.56)	6,844 (76.65)
Yes	894 (26.44)	2,085 (23.35)
Garbage Disposal by Dumping/Throwing*		
No	2,776 (82.11)	7,608 (85.21)
Yes	605 (17.89)	1,321 (14.79)
Garbage Segregation		
No	875 (35.21)	2,068 (32.38)
Yes	1,610 (64.79)	4,318 (67.62)

****p<0.001 as very highly significant and **p<0.01 as highly significant based on a chi-square test.*

In terms of ethnicity, the majority of participants with either insufficient (91.93%) or adequate (94.75%) UIC did not belong to any reported ethnic or indigenous people group. Meanwhile, with regard to household wealth index, insufficient UIC was most prevalent among participants in poor households (49.19%), followed by the rich households (30.29%) and middle-income counterparts (20.53%).

Similar to household wealth index, educational attainment followed a consistent pattern across both UIC groups. Most participants with insufficient UIC had reached high school level (47.53%), followed by college (29.40%), and elementary level (20.91%). Similar trends were noted among those with adequate UIC. For occupation, the majority of respondents in both insufficient and adequate UIC groups had no current job, although a notable portion were engaged in skilled or elementary occupations (Table 3).

Differences in WASH-related factors, except for the type of dwelling unit, were also noted. More than half of the participants with insufficient UIC had a level 3 drinking water source (53.68%), followed by a level 1 point source for drinking water (39.49%). A high proportion of participants with insufficient UIC utilized untreated water (72.23%). Of those who employed water treatment, insufficient UIC status was observed in 9.70% of participants who used filtration and natural disinfection methods, followed by boiling (9.05%) and use of bottled water (8.53%). Similar distributions were noted among participants with adequate UIC levels in terms of drinking water source and water treatment practice. On the other hand, those with adequate UIC tend to use bottled water more (9.65%), followed by boiling (8.53%), and filtration/natural disinfection methods (7.28%) (Table 3).

For toilet facilities and methods of garbage disposal, the majority of WRA in both UIC status subgroups had water-sealed toilets. More than half of the participants in these groups further disposed of garbage either through burning, a compost pit, dumping, or throwing. A higher percentage of participants with insufficient UIC managed garbage disposal without a collection system (55.58%), whereas most of those with adequate UIC had utilized one (54.83%). Lastly, a significant proportion of WRA in both the insufficient and adequate UIC subgroups were found to practice garbage segregation. Details are presented in Table 3.

Association of WASH-related Factors with UIC Levels among Filipino WRA

While holding other variables constant, several factors were found to be significantly associated with UIC levels among WRA. These include having level 3 water systems, type of water treatment modalities (particularly using bottled water), garbage disposal through collector systems, age, ethnicity, and nutritional status of WRA, household wealth index, type of dwelling unit, present occupation, and household salt iodine concentration. The details are shown in Table 4. However, the width of the 95% confidence intervals suggests a high degree of variability in the data, which must be taken into account when interpreting the findings.

Water Source and Treatment

Findings of this study revealed that WRA having a level 3 water system (*e.g.,* piped water) was associated with significantly higher UIC levels compared to having a level 1 sources (*e.g.,* wells or springs) (adjusted effects = 14.02 μg/L; 95% CI: 6.28, 21.77; p <0.001). In relation to the water source, drinking from bottled water was associated with a significant decrease of 14.54 μg/L (95% CI: -26.06, -3.01; p = 0.013) in average UIC level compared to their no-treatment counterparts. Furthermore, the use of alternative filtration and natural disinfection was associated with a 10.78 μg/L decrease in the mean UIC level of WRA compared to their no-treatment counterparts, although the difference is not statistically significant (95% CI: -22.16, 0.59; p = 0.063).

Garbage Collection and Type of Toilet Facility

Environmental and waste management conditions had associations with UIC. After holding the other variables constant, having their garbage collected by a service was associated with significantly higher UIC levels (adjusted effects = 10.81 μg/L; 95% CI: 1.18, 20.44; p = 0.028). However, no significant association was found for other garbage disposal systems in terms of affecting the UIC levels of WRA. This is similar to the type of toilet facility, indicating that there was insufficient evidence that the type of toilet facilities in the household were associated with a change in UIC levels.

Nutritional Status and Sociodemographic Covariates

Holding other variables constant, WRA with normal nutritional status had significantly higher UIC levels on average compared to their underweight counterparts (adjusted effects = 13.36 μg/L; 95% CI: 2.21, 24.52; p = 0.019). In addition, the results suggest that an increase in age is associated with a decrease in UIC levels. On average, compared to their adolescent counterparts, young women had a UIC level of 20.00 μg/L lower (95% CI: -35.73, -4.27; p = 0.013); prime reproductive women had a UIC level of 32.69 μg/L lower (95% CI: -50.24, -15.15; p <0.001), and late reproductive women had a UIC level that was 53.36 μg/L (95% CI: -71.15, -35.57; p <0.001) lower.

Moreover, WRA who were identified as part of an ethnic group or indigenous people had a UIC level 22.55 μg/L lower compared to their counterparts (95% CI: -35.36, -9.73; p <0.001). In terms of wealth quintile, participants in the middle-income group had higher UIC levels as compared to the poorest and poor quintiles (adjusted effects = 10.14 μg/L; 95% CI: 1.74, 18.54; p = 0.018). Related to wealth quintiles, living in non-residential dwelling units was also found to be positively associated with UIC levels (adjusted effects = 104.18 μg/L; 95% CI: 0.99, 207.37; p = 0.048) as compared to WRA housed in residential units.

Furthermore, participants with elementary jobs had higher UIC levels compared to their unemployed counterparts (adjusted effects = 10.59 μg/L; 95% CI: -1.83, 23.01; p = 0.095), although this relationship was not statistically significant. This observation was similar among WRA who were employed in the agriculture, forestry, and fishery sectors, who had significantly higher UIC levels compared to their unemployed counterparts (adjusted effects = 16.20 μg/L, 95% CI: 0.58, 31.81; p = 0.042). Lastly, the iodine concentration of salt in the household was also associated with an increase in UIC levels of WRA by 0.96 μg/L per every unit increase in the ppm of iodine in salt (adjusted effects = 0.96 μg/L; 95% CI: 0.79, 1.14; p <0.001) (Table 4). The width of the confidence intervals suggests a high degree of variability in the data.

Table 4. Association of WASH and Related Parameters with UIC Levels among WRA in the Philippines, 2018-2019, 2021

Predictors	Adjusted Effects [95% CI]	*p*-value
Source of Drinking Water		
Level 1	*Ref*	-
Level 2	3.34 [-9.28, 15.96]	0.520
Level 3	**14.02 [6.28, 21.77]**	**<0.001**
Type of Water Treatment Modalities		
No treatment	1.0	-
Filtration and natural disinfection	-10.78 [-22.16, 0.59]	0.063
Boiling	-4.00 [-15.12, 7.12]	0.481
Use of a sterilizing agent	-40.46 [-89.86, 8.94]	0.108
Use of bottled water	**-14.54 [-26.06, -3.01]**	**0.013**
Type of Toilet Facility		
No toilet facility at all	1.0	-
Sealed	7.63 [-9.38, 24.64]	0.379
Pit System	-26.76 [-67.93, 14.41]	0.203
Garbage Disposal by Collector System		
No	1.0	-
Yes	**10.81 [1.18, 20.44]**	**0.028**
Garbage Disposal by Burning		
No	1.0	-
Yes	3.53 [-4.19, 11.24]	0.370
Garbage Disposal by Compost Pit		
No	1.0	-
Yes	-2.97 [-11.54, 5.59]	0.496
Garbage Disposal by Dumping/Throwing		
No	1.0	-
Yes	-3.31 [-12.71, 6.09]	0.490
Garbage Segregation		
No	1.0	-
Yes	-2.94 [-9.73, 3.85]	0.396
Age (years)		
Adolescents (15-19)	1.0	-
Young women (20-24)	**-20.00 [-35.73, -4.27]**	**0.013**
Prime reproductive women (25-34)	**-32.69 [-50.24, -15.15]**	**<0.001**
Late reproductive women (35-49)	**-53.36 [-71.15, -35.57]**	**<0.001**
Nutritional Status		
Underweight	1.0	-
Normal	**13.36 [2.21, 24.52]**	**0.019**
Ethnicity		
Without ethnicity	1.0	-
With ethnicity	**-22.55 [-35.36, -9.73]**	**0.001**
Household Wealth Index		
Poorest and poor	1.0	-
Middle	**10.14 [1.74, 18.54]**	**0.018**
Rich and richest	7.92 [-0.52, 16.36]	0.066
Type of Dwelling Unit		
Residential	1.0	-
Non-residential	**104.18 [0.99, 207.37]**	**0.048**
Other dwelling/housing units	8.73 [-70.29, 87.74]	0.829
Present Occupation		
No occupation/Housekeeper/Student/Pensioner	1.0	-
Elementary occupations	10.59 [-1.83, 23.01]	0.095
Skilled agricultural, forestry, and fishery workers	**16.20 [0.58, 31.81]**	**0.042**
Other skilled workers	131.11 [-27.53, 289.75]	0.105
Professionals)	16.34 [-49.08, 81.75]	0.624
Salt Iodine PPM Concentration (Dry)	**0.96 [0.79, 1.14]**	**<0.001**

DISCUSSION

This cross-sectional study determined the association of WASH-related factors with UIC levels among WRA in the Philippines. Access to improved and clean water sources and an efficient waste collection system, along with age, nutritional status, and other sociodemographic factors (*e.g.,* ethnicity, socioeconomic status, dwelling type, occupation, and household salt iodine content), were significantly associated with UIC levels in this population.

Sociodemographic Characteristics, Nutritional Status, and WASH

Existing literature suggests that the sociodemographic characteristics of individuals can significantly shape WASH behaviors. These include age, sex, civil status, wealth index or socioeconomic status, employment status, educational attainment, and ethnicity.[25-35] Majority of the Filipino WRA in this study were between the ages of 25-49 years (*e.g.,* prime and late reproductive stages in women), which represents an important age group that traditionally manages household food preparation and water handling, particularly in rural and low-resource settings.[36] WASH behaviors, such as safe water handling and hand hygiene, were reported to influence nutrient preservation by preventing contamination and the spread of diseases.[37,38] Women in this age group are often responsible for ensuring nutritional security in families and households, but often face their own nutritional deficiencies. Previous studies further reported that age significantly influences hygiene behavior, and patterns have been observed across age groups. Specifically, WRA aged 25-34 years exhibited a poorer understanding of best WASH practices in contrast to older groups, suggesting that younger WRA tend to often address immediate concerns over broader health issues such as WASH.[26,39] However, significant gaps exist to date with a limited number of studies directly comparing age and gender differences with WASH outcomes. This necessitates the conduct of further research.

The findings of the current study also presented an important connection between socioeconomic status (SES) and WASH, as lower SES has been linked to poorer WASH access and practices, while higher SES has been associated with better WASH conditions and health outcomes.[14,33] Almost half of the Filipino WRA respondents in this study, however, belonged to low-income households. Low SES is often associated with limited access to improved water and sanitation facilities that may influence WASH-related behaviors such as handwashing, safe water storage, hygienic toilets, and even food hygiene practices. This, in turn, indirectly affects nutrient retention and overall health.[40] Despite the number of reports that demonstrated the strong, positive correlation between SES and WASH, future research should examine how socioeconomic gradients and disparities influence WASH access and practices among WRA for potential effect modification while investigating the exact mechanisms that underlie nutritional outcomes in this population.[31,32,41.42]

Studies further showed that occupation can significantly influence the WASH behaviors of individuals, primarily through education, economic status, and specific workplace environment factors. Higher-income employment is generally linked to better living conditions, thereby supporting necessary infrastructures for good hygiene and sanitation.[43] Many of the Filipino WRA respondents in this study were either housekeepers, small-scale workers, or had no work. Limited employment or income-generating opportunities may potentially reduce the ability to invest in clean water storage, sanitation infrastructure, and kitchen set-ups needed to maintain the nutrients in food, including iodine.[40] Similarly, the majority of WRA respondents attained a high school education, which is consistent across the Philippines.[44,45] These findings indicate that limited economic resources may pose challenges to accessing higher education and could potentially impact opportunities for socioeconomic advancement, which indirectly influence WASH practices and behaviors.[14,46]

Most of the WRA respondents additionally lived in residential dwellings. Stable housing can support consistent access to clean water and sanitation facilities, which support hygienic food and water handling practices.[47] Meanwhile, inclusion in an ethnic group has been similarly reported to influence WASH behaviors as a result of the combined, interacting effects across cultural, social, and economic factors.[35] Ethnicity was notably reported to have the highest predictive value on sanitation and lowest access to water in a study conducted in a lower-middle-income country, just like the Philippines.[34]

On the other hand, a large proportion of Filipino WRA in this study had a normal nutritional status, although there was still a small portion who were underweight. Undernutrition is exacerbated by a poor WASH environment that results in repeated cycles of infection and food contamination, which has been associated with low UIC, possibly through reduced iodine absorption and utilization.[48,49] Additional research work is therefore warranted to further explore the associations between sociodemographic subgroups and WASH-related factors in order to effectively inform WASH-nutrition interventions that are targeted to Filipino WRA.

Disaggregation of Demographic Characteristics by UIC Status

The findings of this study suggest a possible connection between demographic profile and urinary iodine concentration status among Filipino women of reproductive age. Previous literature supports the idea that age, household wealth or socioeconomic status, and occupation or current job are important factors in determining iodine levels.

It has been shown that age is negatively associated with UIC, with older WRA (*e.g.,* 20-49 years old) having lower iodine levels than adolescents (*e.g.,* 15-19 years old). UIC levels were progressively lower across increasing age groups. These are congruent with previous studies and reports that generally reported lower UIC levels in older adults.[50-52] A possible explanation for this trend is that iodine intake, metabolism, and renal iodine clearance may decline with age.[8,53,54] Specific underlying mechanisms may involve changes in dietary patterns, decreased consumption of iodine-rich foods, and altered iodine homeostasis with aging.

In terms of household wealth or socioeconomic status, the middle-income and rich WRA respondents showed better UIC status as compared to poorer households. A similar observation among Filipino WRA in the 2013 NNS has been previously reported by Serafico and colleagues, suggesting that socioeconomic disparities are associated with differences in UIC levels.[6] Filipino WRA in the lowest wealth quintile had specifically 56% lower odds of accessing adequately iodized salt than those in the highest quintile.[6] It was further shown in the study of Knowles and group that in the Philippines (and other countries that were surveyed), only a small proportion of households in the lowest wealth quintile at the national level had used adequately iodized salt, as compared to the highest quintile (17.3% against 39.4%).[55] This indicates that the household wealth index is positively correlated with iodine concentration, implicating better iodine status in wealthier families. Poorer households or those in low socioeconomic status had notably lower access to iodized salt and iodine-dense foods, which potentially makes them more susceptible to iodine deficiency.[50,56,57] Thus, even when salt iodization programs exist, WRA from families with low socioeconomic status will likely tend to use coarse or agricultural salt, which is often inadequately iodized due to its availability and supply.[58]

Occupation and current job parameters further revealed a higher proportion of WRA with inadequate UIC status among those who either reported no occupation, had worked as a housekeeper, had been involved in elementary occupations, or had been engaged in skilled agricultural, fishery, and forestry jobs, as compared to other employment categories. This suggests that women with elementary occupations or those in the agriculture, fishery, and forestry may be exposed to contaminated water sources and more physically demanding work that could limit time for proper food preparation.[59,60] These occupational hazards potentially contribute to iodine deficiency by increasing the risks of diarrheal and infectious diseases that impair nutrient absorption and by reducing access to iodine-rich foods. At the same time, the high proportion of UIC-insufficient WRA who were non-working or housekeepers is consistent with an observed positive association between employment status and access to adequate iodine.[61]

Association of WASH-related Factors with UIC Levels among Filipino WRA

Water Source and Treatment

One of the notable findings of the current study is the presentation of substantially increased UIC levels (14.02 μg/L higher from reference) among Filipino WRA who had access to level 3 sources of drinking water, compared to their counterparts who relied on level 1 point-source water. A level 3 drinking-water supply system has a source, a reservoir, a piped distribution network, and household taps (*i.e.,* waterworks system with individual house connections), which requires adequate treatment for disinfection to ensure water safety.[23] This finding implies that improved water access may facilitate safer water handling, better food preparation, reduced contamination risk, and minimized iodine losses, as opposed to what may occur during the collection, storage, and consumption of drinking water from unprotected sources.[62,63]

In a recent study, household water was reported to be the primary source of iodine among Somaliland women in Africa, and household water iodine concentration strongly correlates with UIC levels.[64] Iodine intake in Somalia has also been previously reported as more than adequate, with household drinking water serving as one of the significant determinants of iodine status among WRA.[65] It should be noted, however, that the household water in this region is primarily supplied by tanker trucks that provide deep and shallow groundwater, in addition to water from public taps, which are different from a level 3 waterworks system.[23,64] Meanwhile, it was also suggested that the consumption of unfiltered tap water was associated with total daily iodine intakes that were below the recommended dietary allowance and estimated average requirement, and that the reliance on desalinated drinking water was also associated with insufficient iodine intakes that cause IDDs.[66] Desalinated water, in the context of Philippine National Standards for Drinking Water, is considered a potential source for a level 2 or 3 water supply system.[23] These reports, along with the findings of the current study, indicate that iodine status can be potentially influenced by the different iodine contents of household drinking water.

Surprisingly, WRA who used level 2 sources (*i.e.,* communal faucet systems) demonstrated intermediate but non-significant association with UIC levels (3.34 μg/L higher from reference). This suggests that partial improvement of the water delivery infrastructure may be associated with inadequate WASH, which may have limited potential to support better health outcomes.[37]

In addition to improved water access, water treatment modalities were also found to be associated with the UIC levels of Filipino WRA in this study. It should be noted that all types of household water treatment were associated with relatively lower UIC levels, where the use of bottled water has demonstrated significant inverse association with UIC. Water service providers in the Philippines rely mainly on conventional water purification methods that include coagulation, flocculation, sedimentation, filtration, and pre-, intermediate, and post-chlorination to comply with specific national water quality standards.[23,67] At the household level, the most common methods of treating water (*i.e.,* boiling, adding chlorine, or using filters) are shown to make water safe from pathogenic bacteria, viruses, and protozoa.[68] On the other hand, standard parameters for bottled drinking water (as a food product) are being monitored and regulated by the Food and Drug Administration of the Department of Health (DOH).[67]

It has been reported, however, that certain treatment methods may reduce micronutrient contents or fail to eliminate microbial contaminants that affect nutrient metabolism.[69-71] For instance, chlorination can cause the removal of essential minerals (*i.e.,* iron, manganese, etc.) and micronutrients that include iodine.[71,72] Chlorination during water purification was shown to eliminate more than 50% of iodine from drinking water for an initial iodine concentration lower than 250 μg/L, whereas complete elimination was observed for an initial iodine concentration of 16 μg/L.[73] Desalination similarly removes dissolved salts from drinking water, including iodine, which is one of the major elements found in seawater.[71] On the other hand, natural disinfection methods have been less effective in totally eliminating pathogens that are linked to diarrheal diseases and malabsorption that impact iodine utilization in the body, which contribute to iodine deficiency.[7,8]

Additional studies further indicate that iodine in groundwater is bound in humic substances produced from the decomposition of plant and animal tissues, and that free iodine may coexist in drinking water.[74,75] Hence, removal of organic matter in drinking water lowers the amount of humic substances and, therefore, the iodine concentration of drinking water. Interestingly, humic substances in water were also reported to have goitrogenic properties.[76] It is possible that humic substances, if present in level 2 household water, may reduce the bioavailability of iodine while potentially increasing the risk of IDDs through the inhibition of thyroid deiodinase enzymes.[76] Studies on the mechanisms underlying iodine absorption and regulation from drinking water consumption are still limited. This necessitates further investigation.

Garbage Collection

Another important finding of this study is the observation of significantly higher UIC levels (10.81 μg/L higher from reference) among WRA participants who had employed a regular garbage collection by municipal or private systems as the usual practice of waste disposal in the household. This association suggests that proper waste disposal may be linked to a lower likelihood of contracting infectious diseases.[77] Interestingly, other traditional household garbage disposal practices, such as burning, composting, and dumping/throwing, did not show any significant associations with UIC levels among Filipino WRA in the analyses. This may indicate that these methods lack sufficient consistency or coverage in relation to UIC levels.

There have been disparities between rural and urban waste management systems in the country, where rural areas had generally poorer coverage and implementation (*i.e.,* ~40% versus 85-90% coverage, respectively), due to irregular/infrequent garbage collection, low number of inadequate garbage trucks, and lack of functional materials recovery infrastructures, among others, in rural communities compared with urban areas.[78-80] The poor waste management in rural areas creates an environment where parasites and disease vectors thrive, which often contributes to the contamination of food and water supplies.[63] When infected by these agents, they can lead to diarrheal diseases and parasitic malabsorption syndromes that impair nutrient absorption, including iodine, through damaged intestinal lining and induced chronic gut inflammation.[81-83] Thus, Filipino WRA residing in rural areas may experience compounded vulnerabilities as a consequence of inadequate waste collection services and increased risks of parasitic diarrheal diseases.

This study highlights the role of WASH interventions that encompass not only water and sanitation but also broader environmental health. By improving sanitation and maintaining a cleaner environment, proper garbage collection services may potentially reduce infection risk and support optimal nutrient metabolism.[11,63] Scientific evidence to support the association between proper garbage collection and iodine nutrition status is, however, currently scarce. Hence, more research is needed to establish causality between poor waste management or general sanitation problems and iodine status.

Type of Toilet Facility

While the type of toilet facility in the household (*e.g.,* sealed, pit system, or no toilet facility at all) showed expected patterns in the analyses, findings from the multivariate analysis did not demonstrate statistical significance. Sealed toilet facilities that were observed to be more common in the households of Filipino WRA demonstrated a positive association with UIC levels (7.63 μg/L higher from reference), whereas pit systems were associated with lower UIC levels (26.76 μg/L lower from reference). The null findings are remarkably surprising given the established importance of sanitation, particularly proper toilet facilities, in preventing fecal contamination and the spread of infectious diseases.[37,62,63,77] Potential explanations include the high proportion of participants (95%) with sealed toilet facilities, which may limit statistical power to detect differences across facility types, or confounding by other sanitation-related factors (*e.g.,* shared versus private facility use, regularity of emptying pit latrines, etc.) not fully captured in the analysis.[84,85]

Nutritional Status and Sociodemographic Covariates

A normal nutritional status, defined in this study as having a healthy BMI of at least 18.5 kg/m^2, emerged as one of the significant positive predictors of UIC levels among Filipino WRA. Compared to underweight participants, those with normal nutritional status had a 13.36 µg/L higher UIC, which was similar to the results of a study conducted among Brazilian women.[86] This reflects that WRA with adequate BMI, who may be assumed to have desirable overall nutritional status, had sufficient caloric intakes and presumably had consumed more iodine-rich foods that led to better UIC levels.[10] In contrast, another study among South Indian women had reported that BMI was not correlated with iodine status, and that extremely higher BMI was instead negatively correlated with UIC levels.[87,88] The latter implicates a non-linear or U-shaped type of relationship, with both undernutrition and obesity affecting iodine status, which is similar to what has been observed with other micronutrient status.[89] The relationship between BMI and UIC levels, therefore, requires careful interpretation.

Iodine nutrition status is regarded as complex and may further be influenced by a number of socioeconomic factors, as illustrated from the additional findings of this study. In particular, a progressive decline in age (*e.g.,* 20.00 µg/L lower UIC at 20-24 yrs; 32.69 µg/L lower UIC at 25-34 yrs; 53.36 µg/L lower UIC at 35-49 yrs) and being part of an ethnic or indigenous people group (22.55 µg/L lower UIC from reference) were negatively correlated with UIC levels among Filipino WRA. Conversely, a middle-income SES status (10.14 µg/L higher UIC from reference); living in a non-residential unit (104.18 µg/L higher UIC from reference); being employed in skilled agricultural, forestry, and fishery works (16.20 µg/L higher UIC from reference); and household salt iodine content (0.96 µg/L higher UIC from the reference) were all associated with significant increases in the UIC levels of Filipino WRA.

The observed negative association between age and UIC levels warrants age-specific dietary adjustments for women aged 35 years and over, who also comprised the largest age group in the study, as they are primarily responsible for household food decisions and meal preparations.[36,90] The negative association with ethnicity may reflect the limited access to adequately iodized salt or certain cultural food preferences with lower iodine content among ethnic groups or indigenous peoples, which underscores the importance of culturally tailored interventions for these communities.[91] The finding that better-income households were associated with better iodine status suggests that a focus on poorer households should be prioritized, probably through subsidies that will make iodized salt more affordable and accessible in this group.[3] In terms of the type of dwelling, although almost all of the study participants lived in residential units, the higher UIC levels associated with non-residential dwelling units may indicate better access to diverse food sources and adequately iodized salt.[56] Lastly, an increased involvement in agriculture and fishery implies a potential boost in household dietary diversity, which leads to positive nutritional outcomes.[92] Such findings clearly emphasize the need for targeted interventions to also cover socio-economic groups in ensuring adequate iodine nutrition among Filipino WRA.

The finding that household salt iodine concentration was significantly associated with UIC levels among Filipino WRA corroborates the claim that universal salt iodization can serve as a primary strategy to address and mitigate iodine deficiency in the country.[3,56-58,61] Data from the 2008 NNS revealed that only 19.5% of the surveyed households had adequately iodized salt (*e.g.,* 20-70 ppm).[93] Moreover, the median iodine level in salt was only 5.28 ppm, which was notably lower than the international standards set by the WHO/UNICEF/ICCIDD.[7,93] The positive association found between iodine salt content and UIC in this study indicates that access and utilization of adequately iodized salt at the household level are similarly critical to ensure optimal iodine levels, in addition to the iodization of all food-grade salt for consumption through the ASIN Law.[2] This approach can substantially impact iodine status at the population level, especially targeting the pockets of iodine deficiency identified among vulnerable populations that include women of reproductive age.

Implications for Public Health Policy and Practice in the Philippines

The findings of this study have important implications for integrated WASH and nutrition programming in the country. This study underscores the importance of sustaining and strengthening the Universal Salt Iodization program while simultaneously integrating improved WASH into nutrition-sensitive interventions. With the recent enactment of the Philippine Salt Industry Development Act, which aims to revitalize domestic salt production in support of the implementation of ASIN law, it is important to ensure that progress in iodine nutrition will not be inadvertently compromised by provisions that make iodization optional for artisanal and non-food grade salt.[94] Nonetheless, the reported associations in this study suggest that iodine nutrition status may not be solely determined by dietary intakes, but may be further influenced by broader environmental and hygiene conditions. This calls for a multisectoral approach that simultaneously focuses on water and sanitation, nutrition, and health programs to ensure optimal iodine nutrition among Filipino WRA, particularly in resource-limited communities.

A more coordinated planning between agencies responsible for WASH infrastructure (*e.g.,* local government units and local water districts) and nutrition programs (*e.g.,* DOH, National Nutrition Council and local government units) must be prioritized when investing in WASH in iodine-deficient areas in order to maximize nutrition benefits. The reported positive association between level 3 water sources and UIC provides additional justification for expansion of piped water infrastructure, while the findings on garbage collection support stronger enforcement of the Ecological Solid Waste Management Act of 2000 in underserved areas.[95] These will lead to further prevention of diarrheal diseases and substantially reduce infectious disease burden, which is associated with improved iodine absorption, reduced iodine losses, and better thyroid function. Ultimately, improvements in WASH should be viewed as complementary strategies rather than alternatives to salt iodization as the primary intervention.

Limitations of the Study

The secondary data from the PUFs of the DOST-FNRI were extracted and analyzed in this study. Although the ENNS is a nationally representative, population-based survey that aims to characterize the nutritional status and overall health of the Filipino population, the data were collected to address different objectives. Due to the secondary nature of data, a more comprehensive characterization of the current state of WASH among Filipino WRA was not done. Additionally, the WASH variables derived from the ENNSs may be subject to measurement error and recall bias for self-reported practices such as water treatment methods, garbage disposal, and waste segregation behaviors, possibly underestimating the true association between poor WASH and low UIC levels. Second, the study utilized a cross-sectional design. This means that causality cannot be established from the findings because the data were gathered at a single point in time. The study findings may not be generalizable to other WRA populations in low- and middle-income countries (LMICs) with different WASH profiles and varying iodization compliance. For instance, in settings with more effective universal salt iodization compliance, the magnitude or direction of the reported associations may differ. Nonetheless, the study findings are likely relevant to LMICs experiencing similar challenges in terms of safe and clean water and sanitation access, environmental contamination compromising health, and heterogenous iodization program implementation. Third, despite adjusting for a number of sociodemographic and household-level covariates in the regression models, residual confounders that are potentially associated with both WASH factors and iodine status (*e.g.,* household food security status, prevalence of diarrheal diseases or parasitic infections, etc.) may partially explain the observed associations. For instance, adjusting for wealth index as a covariate may not absolutely capture the socioeconomic status of a household, which influences both access to WASH and dietary practices. Furthermore, no subgroup analyses or tests of interaction were performed in this study, which may constitute another limitation as the observed associations between WASH-related factors and UIC levels among Filipino WRA could vary across sociodemographic groups. These may have important implications for more targeted interventions. Survey weights were also not applied in the analyses, which may limit the generalizability of the findings to the broader Filipino population. Lastly, dietary iodine intake was not directly assessed. Iodine nutrition status is primarily a reflection of the recent dietary intakes of individuals. Aside from UIC, which is a widely used indicator in assessing the iodine status of a population, all potential sources of dietary iodine must be accounted for. This will provide an accurate measurement that combines both urinary and dietary data in identifying iodine deficiency or sufficiency, which, in turn, better reflects the true impact of WASH-related factors and interventions on iodine status.

CONCLUSIONS AND RECOMMENDATIONS

This study provided preliminary evidence on the significant associations of WASH-related factors with UIC levels among Filipino WRA. Findings demonstrated that improvements in strategies concerning better water access, sanitation systems, and hygiene practices, particularly piped access to clean water and regular waste collection, can effectively complement other primary interventions (*i.e.,* universal salt iodization and iodine supplementation) in preventing or treating iodine deficiency. Age, nutritional status, ethnicity, and present occupation of Filipino WRA, as well as socioeconomic status, dwelling type, and salt iodine content of households, were also noted to affect UIC levels. Future research is then recommended to establish causality between WASH and iodine status of Filipino WRA through the conduct of longitudinal studies, and to examine dietary iodine intakes along with WASH exposures.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

Funding Source

None.

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