A Comprehensive Approach for Lead Exposure Reduction: Investigating Sources, Cognitive and Oral Health Impacts, and Public Health Strategies in Rural Areas in Gurgaon India

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Consent forms, questionnaires, and data collection materials.

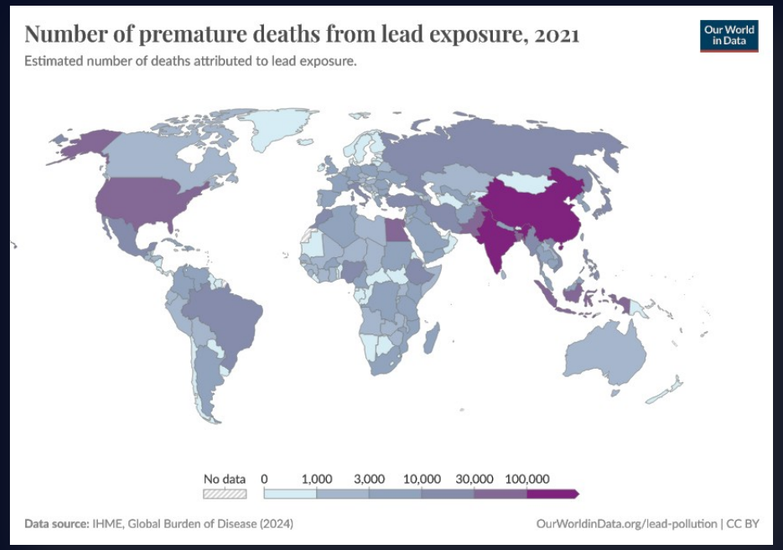
Introduction to Lead Exposure

- Lead: A Toxic Pollutant
- Global Health Crisis
- Elevated Blood Levels

Lead is a hazardous pollutant, affecting one-third of all children globally. India alone accounts for a significant proportion of these cases, with elevated blood lead levels exceeding safety limits in many states.

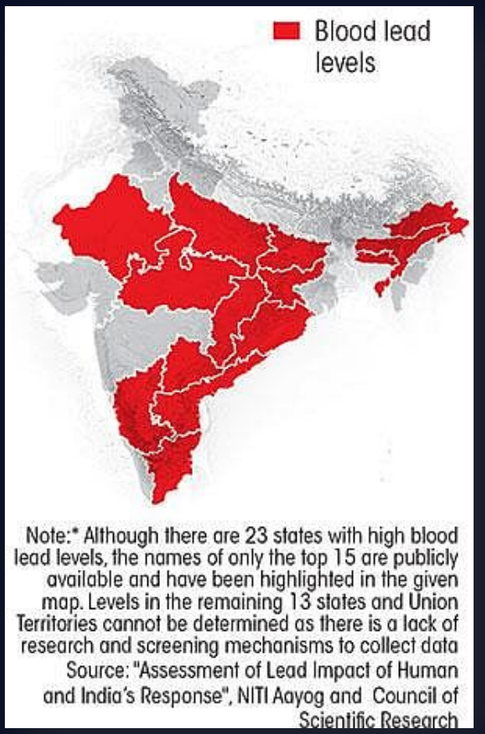
Ericson, B., Landrigan, P., Taylor, M. P., Frostad, J., Caravanos, J., Keith, J., & Fuller, R. (2018). A meta-analysis of blood lead levels in India and the attributable burden of disease. *Environmental Research*, 166, 409–413.

The Silent Threat: Lead Poisoning in India



Global Burden

One-third of all children globally are poisoned by lead. India accounts for 275 million children with elevated lead levels.



Indian Context

23 Indian states exceed the 5 µg/dL blood lead level (BLL) limit. This indicates a widespread public health crisis.

Lead remains a significant public health threat, especially in India. Its pervasive nature demands urgent attention and comprehensive intervention strategies.

- Zhou, Y., Zhang, Y., Wang, Y., Wang, L., & Zhang, X. (2023). Patterns of global burden of 13 diseases attributable to lead exposure, 1990–2019. *BMC Public Health, 23*(1), 1–13
- Pure Earth. (2020). Lead poisoning fact sheet: The global burden of disease.

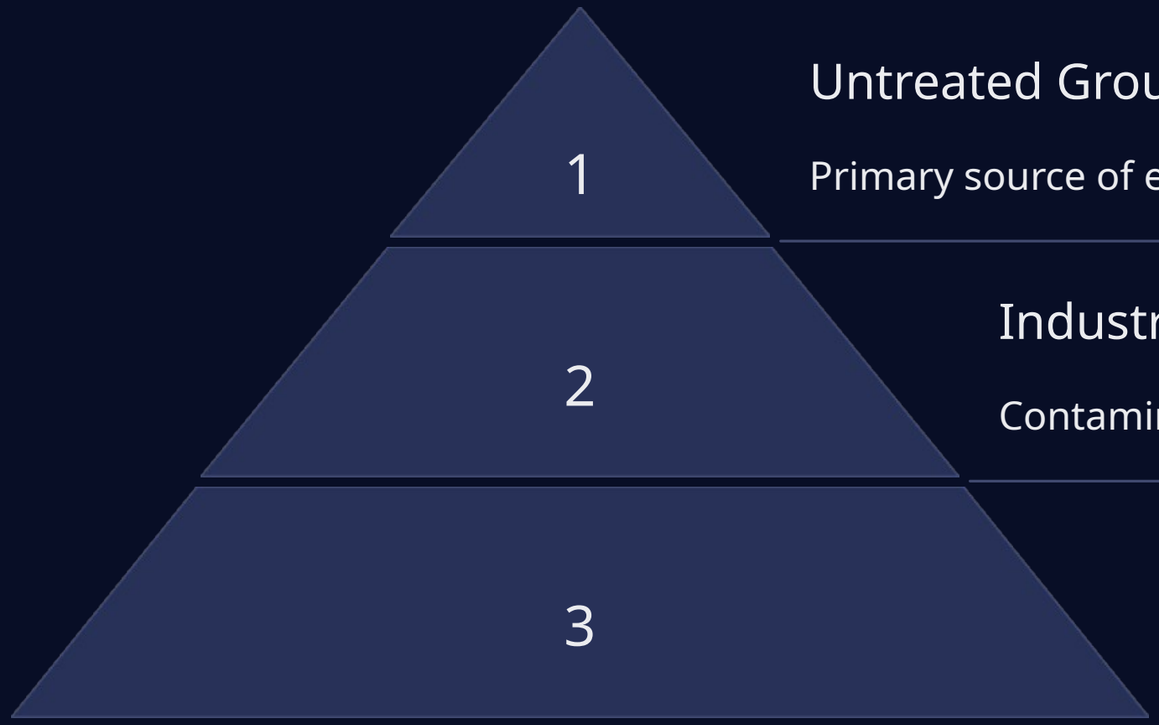
Health Impacts of Lead Exposure

Neurological Damage	Reduced intelligence, attention deficits, lower educational attainment.
Behavioral Issues	Anger management issues, aggressive and violent behaviours.
Organ Damage	Heart and kidney damage in adults, anaemia.
Mortality	Over 230,000 annual deaths in India due to lead exposure.

Lead is a potent toxicant, causing severe and permanent health issues. Children are especially vulnerable due to higher absorption rates, leading to lifelong developmental impairments.

Bellinger, D. C. (2008). Very low lead exposures and children's neurodevelopment. *Current Opinion in Pediatrics*, 20(2), 172–177

Lead Exposure in Rural Gurgaon



Untreated Groundwater

Primary source of exposure.

Industrial Proximity

Contamination from nearby industries.

Poor Pollution Control

Lack of regulatory oversight.

Rural Gurgaon faces heightened lead exposure risks. Industrial activities, untreated groundwater, and inadequate pollution control contribute to this silent threat. Oral ingestion pathways, such as drinking water and food, remain under-researched.

Chakraborty, D., & Saha, R. (2019). Assessment of heavy metal contamination in groundwater in the industrial areas of Delhi and Haryana. *Environmental Monitoring and Assessment*, 191(3), 1–12.

Key Challenges in Lead Exposure Reduction

1

Unregulated Exposures

Lead chromate in spices, lead leaching from cookware.

2

Neglected Surveillance

No routine screening, undiagnosed cases prevalent.

3

Significant Health Burden

Permanent IQ loss, behavioural disorders, organ damage.

4

Local Context Urgency

High problem urgency in rural Gurugram communities.

Lead exposure in rural areas poses a significant public health challenge. Unregulated sources, inadequate surveillance, and severe health impacts underscore the urgency of intervention.

Mathee, A. (2014). Towards the prevention of lead exposure in South Africa: Contemporary and emerging challenges. *Neurotoxicology*, 45, 220–223

Addressing the Research Problem

Ongoing Concern

Lead exposure threatens child health in India.

Intervention Gap

Limited local data on combined interventions.

High-Risk Areas

Gurgaon's rural communities face high exposure.

Vulnerable Children

Lead toxicity impacts cognitive and oral health.

Risk Amplification

Nutritional deficiencies increase lead absorption.

To identify exposure sources and assess impacts. To evaluate cost-effective, community-based interventions, including filtration, supplementation, and awareness programs.

Research Aim and Objectives

To evaluate the effectiveness of an integrated intervention—comprising water filtration, nutritional supplementation, and community education—in reducing lead exposure and improving cognitive and oral health outcomes among children aged 3–12 years in rural Gurgaon, India

Assess Environmental Lead Exposure

To measure baseline levels of lead contamination in groundwater , soil and household dust in selected rural communities of Gurgaon.

Evaluate Baseline Health Metrics

To determine the initial blood lead levels (BLL), cognitive function scores (using the Wechsler Intelligence Scale for Children), and oral health status (plaque and gingival indices) of participating children prior to intervention.

Implement Integrated Intervention

- To administer a 12-month intervention involving
- -Water filtration systems to reduce lead in drinking water.
- Nutritional supplements focusing on calcium, iron, zinc, and vitamin C.
- Community education sessions to raise awareness about lead exposure risks

Measure Post-Intervention Outcomes

To evaluate changes in BLL , cognitive function scores and oral health status of participating children after the 12-month intervention ;

Research Questions and Hypotheses

1

Environmental Lead Baseline

What are the baseline levels of lead contamination in groundwater, soil, and household dust in selected rural communities of Gurgaon?

H_0: No significant contamination; H_1: Significant contamination exists.

2

Child Health Baseline

What are the initial blood lead levels (BLL), cognitive function scores, and oral health status of children aged 3–12 years in the study area

H_0: BLLs within safe limits, no impairment; H_1: Elevated BLLs and compromised health.

3

Intervention Implementation and Acceptance

Was the integrated intervention delivered as planned and accepted by the community?

4

Post-Intervention Outcomes

What changes occur in BLL, cognitive function, and oral health status of participating children after the 12-month intervention?

H_0: No significant change; H_1: Significant improvement.

5

Nutritional Impact

Is there a correlation between calcium supplementation and reduced BLL, improved cognitive scores, and better oral health

H_0: No association; H_1: Significant association.

6

Overall Intervention Effectiveness

How effective is the integrated intervention model in reducing lead exposure and improving health outcomes among children in rural Gurgaon

H_0: No significant impact; H_1: Significant reduction in exposure and improved outcomes.

Core Hypotheses

1 H1: Comprehensive Intervention’s Efficacy

A comprehensive intervention package, combining source removal, nutritional support, and education, will significantly reduce mean blood lead levels in children within the intervention villages compared to baseline measures.

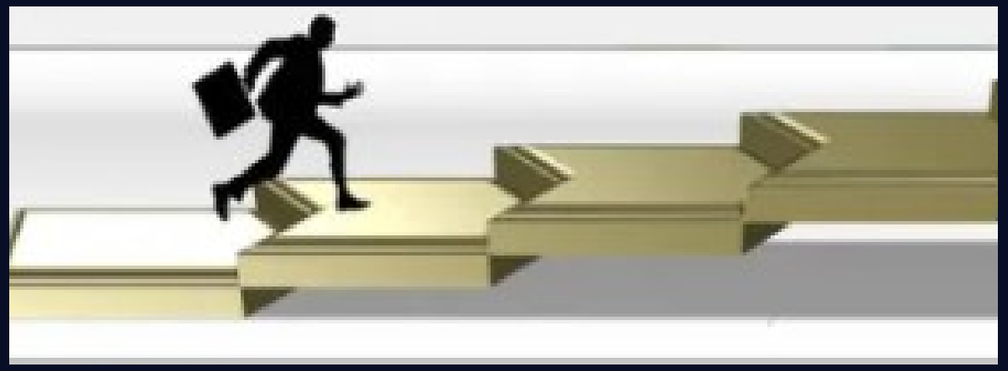
2 H2: Health Outcome Improvements

The observed reduction in blood lead levels will correlate with significant improvements in children's cognitive function scores and their oral health indices.

3 H0: Control Group Stability

Conversely, in the absence of the integrated intervention, there will be no significant change in blood lead levels or associated health outcomes.

Rationale for the Study



Children in rural Gurgaon face significant vulnerability to lead exposure, stemming from pervasive environmental contamination and prevalent nutritional deficiencies. Despite the clear public health imperative, integrated interventions that simultaneously address exposure reduction and health improvements remain largely under-evaluated in such settings. This study seeks to fill this critical knowledge gap by rigorously assessing the impact of a holistic intervention on lead levels and associated health outcomes.

Our approach is grounded in the understanding that Lead Exposure is a complex issue requiring multi-pronged solutions. By targeting both environmental sources and individual susceptibility through nutrition, we aim to provide a scalable model for lead poisoning prevention and mitigation in vulnerable populations. The findings will contribute robust evidence to inform future public health policies and intervention strategies.

Significance, Importance and Expected Impact

This research addresses a crucial gap in understanding and mitigating the pervasive threat of lead exposure among rural children in Gurgaon. By integrating environmental health, nutrition, and oral health, the study provides a holistic perspective on lead's impact and potential interventions. The findings are anticipated to yield evidence-based insights that can inform and shape public health policies at both local and national levels.

Furthermore, the study aims to identify scalable community interventions. Successful models demonstrated here could be adapted and implemented in other regions facing similar challenges, thereby protecting countless vulnerable children from the irreversible harm of lead poisoning. This study represents a vital step towards improving long-term health and developmental outcomes for a significant segment of the population.

Scope

- Evaluates an integrated intervention (water filtration, nutritional supplementation, community education).
- Focuses on lead exposure and cognitive as well as oral health outcomes in children aged 3–12 in rural Gurgaon.
- Includes environmental assessment (groundwater, soil, household dust lead levels).
- Involves biological monitoring (BLL, WISC, plaque and gingival indices).
- Compares pre- and post-intervention data for outcome evaluation.

Literature Review Framework

Section 2.1: Overview of Lead Exposure in Children

Global prevalence and specific challenges in India. Sources of exposure, particularly in rural settings.

Section 2.2: Health Impacts of Lead Exposure

Cognitive and behavioral effects- neurobehavioral deficits, impaired executive functions. Oral health implications, plaque, gingival inflammation, delayed tooth eruption, enamel hypoplasia.

Section 2.3: Role of Nutritional Interventions

Calcium supplementation, mechanism of action, impact on lead absorption. Other nutritional factors- iron and zinc deficiencies and their role in lead toxicity.

Section 2.4: Integrated Intervention Strategies

Effectiveness of multi-faceted approaches combining environmental control, nutrition, and education.

Literature Review: Lead Exposure and Health Impacts

Lead Exposure in Children

Lead remains a pervasive environmental toxin, disproportionately affecting children due to their developing physiological systems. Despite global efforts to phase out leaded gasoline, India faces significant challenges. A meta-analysis indicates a mean BLL of **6.86** µg/dL in Indian children, with some regions, like Chennai, reporting 96% of children with BLLs ≥10 µg/dL. Primary sources include contaminated groundwater, industrial emissions, lead-based paints, and improper battery recycling. Rural areas in Gurgaon are particularly vulnerable due to inadequate infrastructure and limited awareness.

Cognitive and Behavioral Effects

Lead exposure is strongly linked to cognitive deficits. Studies in Chennai show higher BLLs correlate with increased risks of neurobehavioral deficits, including ADHD and impaired executive functions, as well as decreased visual-motor abilities. These impacts can significantly hinder academic performance and long-term developmental outcomes, even at subclinical lead levels.

Oral Health Implications

The impact of lead on oral health, though less explored, is significant. Lead accumulates in dental tissues, contributing to increased plaque formation and gingival inflammation. Elevated BLLs can lead to delayed tooth eruption and enamel hypoplasia, making children more susceptible to dental caries and periodontal diseases. This highlights the systemic nature of lead toxicity, affecting even seemingly distinct health domains.

Ericson, B., Dowling, R., Dey, S., Caravanos, J., Mishra, N., Fisher, S., Ramirez, M., Sharma, P., McCartor, A., Guin, P., Taylor, M. P., & Fuller, R. (2018). A meta-analysis of blood lead levels in India and the attributable burden of disease. *Environmental International*, 121(Pt 1), 461–470.

Chandramouli, K., Steer, C. D., Ellis, M., & Emond, A. M. (2009). Effects of early childhood lead exposure on academic performance and behaviour of school age children. *Archives of Disease in Childhood*, 94(11), 844–848

Sankeshwari, R. M., Ankola, A. V., Tangade, P. S., & Hebbal, M. (2014). Lead exposure and its relation to dental caries in children. *Journal of Toxicology and Environmental Health Sciences*, 6(3), 45–49.

Literature Review: Intervention Strategies

Integrated Intervention Strategies

Addressing lead exposure demands a multifaceted approach. Integrated models combining environmental control, nutritional supplementation, and community education have shown promise. For instance, water filtration systems significantly decrease lead in drinking water, while community education boosts awareness and protective practices. Such integrated strategies are particularly relevant in rural Gurgaon due to prevalent lead sources and nutritional deficiencies, offering potential for substantial reductions in BLLs and associated health risks.

Other Nutritional factors

Deficiencies in iron and zinc also increase lead absorption. Iron deficiency enhances lead, while zinc competes with lead for binding sites. A comprehensive nutritional approach including calcium, iron, and zinc is thus essential for mitigating lead toxicity and its effects.

Calcium Supplementation

Calcium critically mitigates lead absorption by competing for absorption pathways in the gastrointestinal tract. Adequate calcium intake reduces lead absorption, thereby lowering BLLs. Randomized trials and pharmacokinetic models confirm calcium's role in reducing lead absorption and influencing its distribution and retention in the body.

Goyer, R. A. (1995). Nutrition and metal toxicity. *The American Journal of Clinical Nutrition*, 61(3 Suppl), 646S–650S

Ettinger, A. S., Téllez-Rojo, M. M., Amarasiriwardena, C., Peterson, K. E., Schwartz, J., Aro, A., Hu, H., & Hernández-Avila, M. (2006). Influence of maternal bone lead burden and calcium intake on levels of lead in breast milk over the course of lactation. *American Journal of Epidemiology*, 163(1), 48–56.

Literature Review: Global and Local Context

Global Evidence and Economic Impact

Global data unequivocally show lead exposure causes irreversible neurological and systemic harm. The WHO emphasizes that even low BLLs permanently impair children's brain development, leading to reduced IQ, attention deficits, and lower educational attainment. A UNICEF/PureEarth report estimates 275 million Indian children have BLLs exceeding 5 µg/dL, resulting in an estimated annual considerable GDP loss in billions from cognitive deficits. This underscores lead as an urgent developmental and economic threat requiring immediate action.

Indian Studies: Cognitive and Oral Health

Local studies corroborate these global findings. In Chennai, children aged 3–7 years with a mean BLL of 11.4 µg/dL exhibited higher anxiety, social problems, and ADHD scores, with executive function being most affected. These studies confirm that even subclinical lead levels are linked to adverse school behavior and learning outcomes.

Policy Context and Study Contribution

India has made strides in phasing out leaded petrol and is currently phasing out leaded paints, yet significant gaps remain in lead mitigation. Experts recommend national lead-mitigation missions and strict regulation of adulterated products. This study builds on existing evidence, aiming to address local knowledge gaps and rigorously test integrated interventions within the Indian context, thereby contributing to robust, evidence-based policy recommendations.

World Health Organization. (2021). Lead poisoning and health

Palaniappan, M., Roy, A., & Kannan, S. (2011). Lead exposure and behavior among young children in Chennai, India. *Neurotoxicology*, 32(3), 429–434

Gupta, N., & Maheshwari, A. (2021). Lead exposure in India: Progress and challenges in mitigation. *Environmental Science and Pollution Research*, 28(33), 45072–45082.

Identifying Research Gaps in Lead Exposure Interventions

Source Identification in Rural Areas

Lack of comprehensive assessments for all lead exposure sources such as traditional cosmetics and household items in rural Gurgaon hinders targeted interventions.

Role of calcium supplementation in Indian context

There is limited research within the Indian context that considers local dietary habits, nutritional deficiencies, and socioeconomic factors.

Community Awareness and Behavior

Insufficient understanding of how educational programs improve knowledge and preventive practices related to lead risks among rural populations.

Integrated Intervention Studies

Scarcity of research evaluating combined environmental, nutritional, and educational interventions prevents establishing holistic approaches.

Longitudinal Data on Cognitive and Oral Health Outcomes

Longitudinal studies that track changes over time, especially pre- and post-intervention, are limited

Policy Evaluation and Socioeconomic Disparities

Limited data on policy enforcement at local levels and differential intervention outcomes among vulnerable sub-populations remain major gaps.

Theoretical Foundations Underpinning Lead Exposure Research

Ecosocial Theory

Examines systemic and structural determinants influencing lead exposure across social and environmental layers.

Health Belief Model

Guides behavioural intervention planning by understanding individual perceptions and practices related to lead risk.

DOHaD Framework

Highlights the significance of early-life environmental exposures on lifelong health outcomes.

PRECEDE-PROCEED Model

Offers a systematic approach to designing, implementing, and evaluating multi-level health programs.

Conceptual Framework: Environmental and Nutritional Factors

Environmental Determinants

Lead sources include contaminated groundwater, soil, and household dust, with exposure via ingestion, inhalation, and dermal contact.

Nutritional deficiencies of calcium, iron, and zinc increase lead absorption and supplementation mitigates toxicity.

Behavioral and Health Outcomes

Limited caregiver awareness and socioeconomic challenges exacerbate exposure effects, leading to cognitive deficits and oral health issues like plaque buildup and gingivitis.

Interventions target environmental control, supplementation, community education, and policy enforcement.

Conceptual Framework: Integration with National Programs

Alignment with ICDS and NHM

Leveraging existing child health programs facilitates the implementation and sustainability of lead exposure interventions.

Stakeholder Engagement

Continuous feedback with local leaders, schools, and health workers ensures cultural appropriateness and community ownership.

Theory of Change

Reducing environmental lead lowers blood lead levels resulting in improved cognitive scores and reduced dental caries.

Socio-Ecological Model

Integrates lead sources, exposures, health outcomes, and interventions across environmental, biological, and behavioral levels.

Part 2 – Research Methodology

Research Approach: Mixed-Methods Approach

This research employs a convergent parallel mixed-methods design, integrating quantitative quasi-experimental measures with qualitative insights to comprehensively assess lead exposure interventions.

The quantitative arm evaluates the efficacy of water filtration and micronutrient supplementation on blood lead levels and health indices, while the qualitative component explore attitudes, and behaviors via focus groups and interviews.

Study Duration **12** months (December 202**4** to December 2025)

Study setting - Across rural villages of Gurgaon

Intervention Implementation: Multimodal Strategies

Water Filtration

Point-of-use filters installed in high-risk homes reduce lead content in drinking water.

Nutritional Supplementation

Supplements provided to mitigate lead absorption and improve nutritional status.

Educational Campaigns

Community workshops and materials increase awareness and promote preventive behaviors.

Carranza, F. A., & Newman, M. G. (2015). *Carranza's Clinical Periodontology* (12th ed.). Elsevier Health Sciences.

Data Collection Methods:

Quantitative Component

- Questionnaires (Demographics)
- Nutritional Assessment chart
- Biological Sampling - Blood Lead Levels (µg/dL)
- Environmental Sampling – Water, Soil and Household dust Lead Levels (µg/dL)
- Cognitive Function Assessment – Wechsler Intelligence Scale for Children Scores
- Oral Health Indices (Gingival and Plaque index)

Qualitative Component

- Interviews
- Group Discussions
- Observational Studies

Wechsler, D. (2014). *Wechsler Intelligence Scale for Children–Fifth Edition (WISC–V)*. San Antonio, TX: Pearson.

Carranza, F. A., & Newman, M. G. (2015). *Carranza's Clinical Periodontology* (12th ed.). Elsevier Health Sciences.

Tools and Instruments for Reliable Data Collection

Digital Platforms

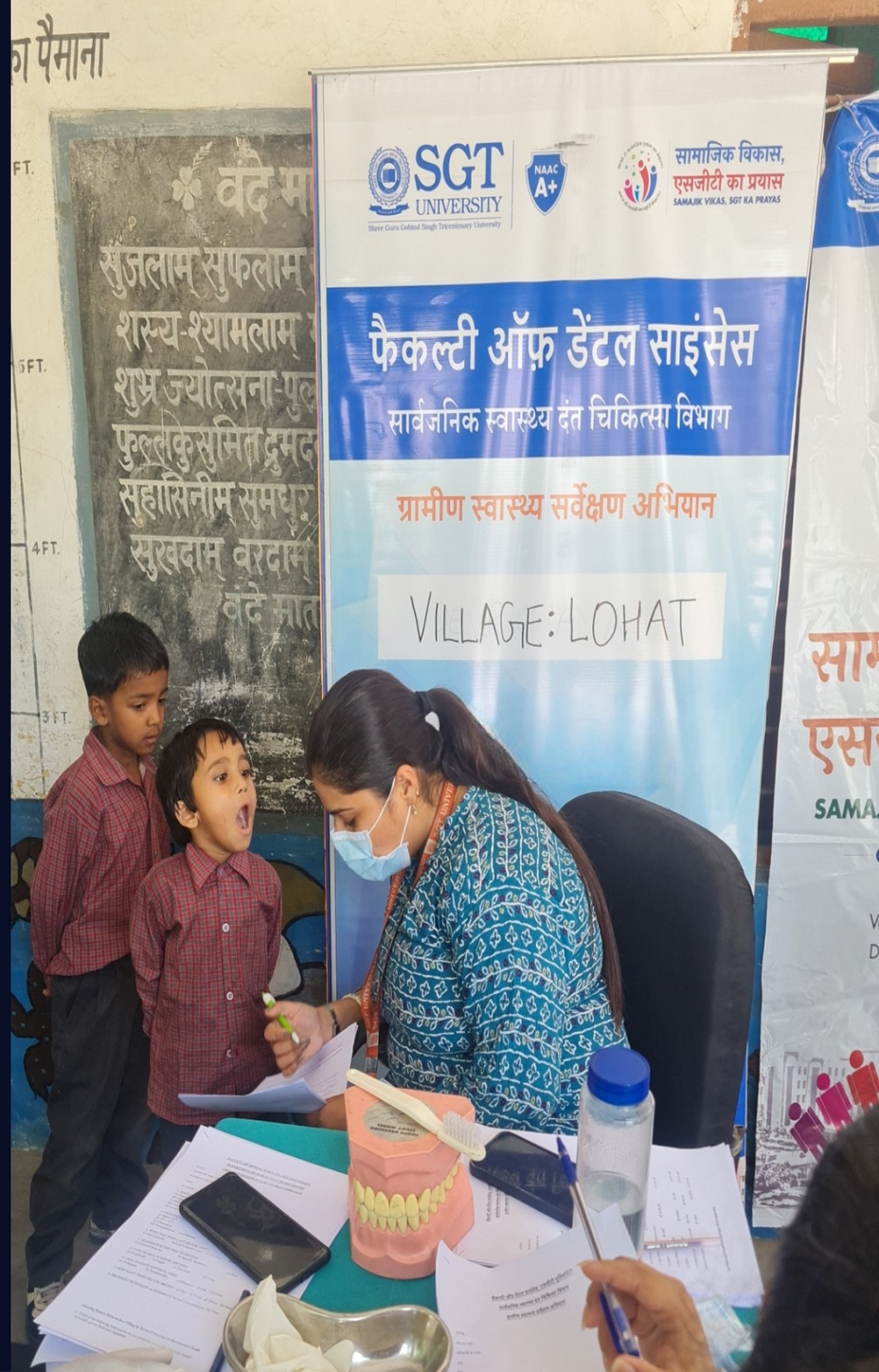
Utilization of excel sheets, ensuring efficient field data management.

Standardized Assessment Instruments

Validated cognitive and oral health tools provide consistent and comparable health measurements across the study population.

Environmental Sampling Equipment

Certified devices accurately collect and analyze water, soil, and dust samples to quantify environmental lead concentrations.



Ethical Considerations in Data Collection

IEC-SGTDCHRI/FDS/PHD/2024/02

1

Informed Consent

Participants and guardians receive transparent explanations of study aims and procedures, consenting voluntarily before involvement.

2

Confidentiality

Data is anonymized, and sensitive information is securely stored to protect participant privacy throughout the research.

3

Cultural Sensitivity

Methods are tailored to respect local customs and languages, fostering participant trust and comfort during data gathering.

Ethical Considerations in Lead Exposure Research

Transparency

Open communication regarding study aims, methods, and findings increases trust and accountability.

Participant Respect

Obtaining informed consent and ensuring confidentiality safeguard participants' rights and dignity.

Adherence to Standards

Compliance with regulatory and ethical guidelines upholds scientific integrity and ensures responsible investigation.

Ethical rigor is critical to conducting research that benefits communities while minimizing harm, reinforcing our commitment to public health principles throughout the project.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Children aged 3–12 years
- Permanent residents of rural Gurgaon, Haryana
- Children free from chronic illnesses affecting study results
- Informed consent obtained from guardians

Exclusion Criteria

- Recent relocation (within 6 months)
- Medical conditions interfering with participation
- Concurrent participation in related clinical studies
- Non-consent from parents/guardians

Study Design: Longitudinal Cohort RCT

1

Longitudinal Cohort

Following 300 children aged 3–12 over 12 months with multiple assessments to track blood lead levels, cognition, and oral health indices.

2

Randomized Controlled Trial [RCT]

Participants randomly assigned to rigorously evaluate the impact of water filtration, nutritional supplementation, and behavioral education.

3

Interventions

- Household water filtration systems
- Supplements including calcium, iron, zinc, and vitamin C
- Community awareness programs on lead exposure prevention

Sampling Methodology: Two-Stage Cluster Sampling

The study employs a two-stage cluster sampling approach for efficient participant selection across rural Gurgaon. Initially, clusters such as villages or neighborhoods are identified, and subsequently, households within these clusters are randomly selected to recruit eligible children.

This sampling technique enhances representativeness and logistical feasibility given the dispersed rural populations, ensuring diverse environmental and demographic profiles are included in the study cohort.

Data Collection Tools for Environmental, Biological and Cognitive Measures

Environmental Tools

- Water sampling kits for lead analysis by (graphite furnace atomic absorption spectrophotometry)
- Soil and dust collection kits for environmental lead quantification by Atomic Absorption Spectrometer (AAS).

Biological and Nutritional Assessment

- Standardized capillary blood lead testing (graphite furnace atomic absorption spectrophotometry)
- 48-hour dietary recall and questionnaires for nutritional status **Dividing the children into the following age brackets, as per the ICMR 2020 guidelines : 3–5 years , 6–9 years, 10–12 years for nutritional assessment**

Cognitive and Oral Health Instruments

- Wechsler Intelligence Scale for Children (WISC) for cognitive function
- Plaque Index and Gingival Index for oral health evaluation

- Dixit, A., Siddaiah, N. S., & Joshi, P. (2020). Spatial variations and abundances of trace metals as linked to landuse pattern: A case study from Gurugram, Haryana, India. *SN Applied Sciences*, 2(8), 1402.
- Chen, J., Xiao, S., Wu, X., Fang, K., & Liu, W. (2005). Determination of lead in water samples by graphite furnace atomic absorption spectrometry after cloud point extraction. *Talanta, 67*(5), 992–996.
- Gupta, A., Tripathi, M., Siddiqui, B. M. A., Upparakadiyala, R., Reddy, P. A., Mohan, D. R., Reddy, K. V., & Sripad, D. V. (2024). Levels of lead in blood and water in occupationally exposed and unexposed population of the Guntur district, Andhra Pradesh: Baseline analysis of a prospective cohort study. *Journal of Clinical and Translational Research, 10*(3), 201–208
- Ramires-Romito, A. C. D., Oliveira, L. B., Romito, G. A., Mayer, M. P. A., & Rodrigues, C. R. M. D. (2004). Correlation study of plaque and gingival indexes of mothers and their children. *Journal of Applied Oral Science, 12*(3), 228–231
I- ndian Council of Medical Research - National Institute of Nutrition (ICMR-NIN). (2020). *Dietary guidelines for Indians - A manual* (2nd ed.). Hyderabad, India: National Institute of Nutrition.

Intervention Implementation

Nutritional Supplementation

After baseline assessments, all participants received a dietary intervention monthly for 3 months. Each child was provided daily chewable calcium carbonate (500 mg elemental Ca), vitamin C (500 mg), and a pediatric multivitamin containing 10 mg iron and 7 mg zinc. Dosages were chosen based on public health guidelines and prior studies . Parents were counseled on enriching the child's diet with dairy, fruits, and iron-rich foods (per CDC recommendations). Supplements were dispensed monthly and adherence (pill counts, parent logs) was monitored. Concurrently, community meetings educated caregivers about Pb hazards (e.g. avoiding lead-glazed pottery, safe disposal of batteries).

Centers for Disease Control and Prevention. (2012). *Guidelines for calcium, vitamin C, iron, and zinc supplementation in children*.

Statistical Tests for Data Analysis

Paired t-test

Evaluates pre- and post-intervention differences within the same group for variables like blood lead levels and cognitive scores.

ANOVA

Compares mean outcomes to assess efficacy.

Repeated Measures Analysis

Models changes over time points accounting for within-subject correlations, key for longitudinal assessments.

Regression Analysis

Examines predictors of cognitive and oral health outcomes based on lead exposure and nutritional factors.

Chi-Square Test

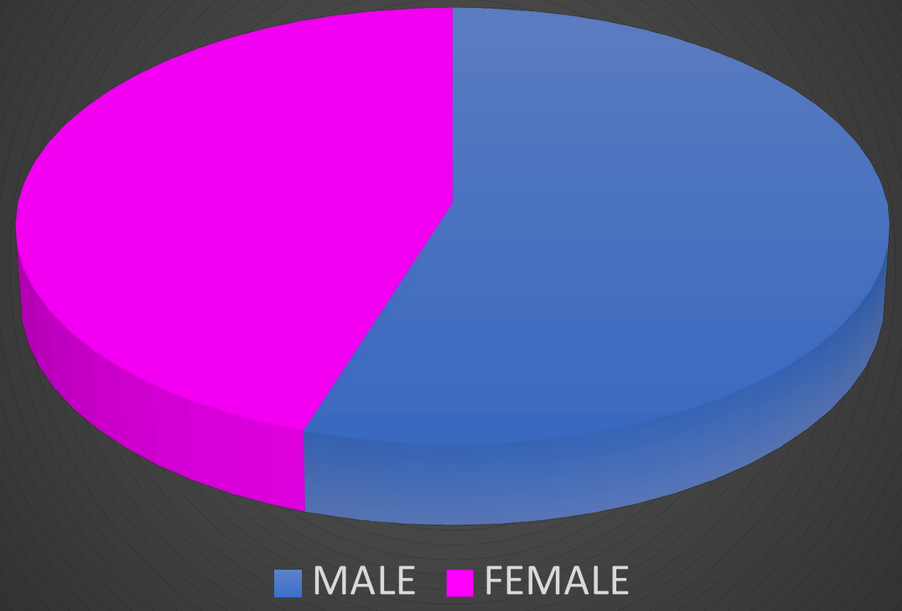
Analyze associations between categorical variables like oral health status and exposure levels, especially in small samples.

Interrupted Time Series

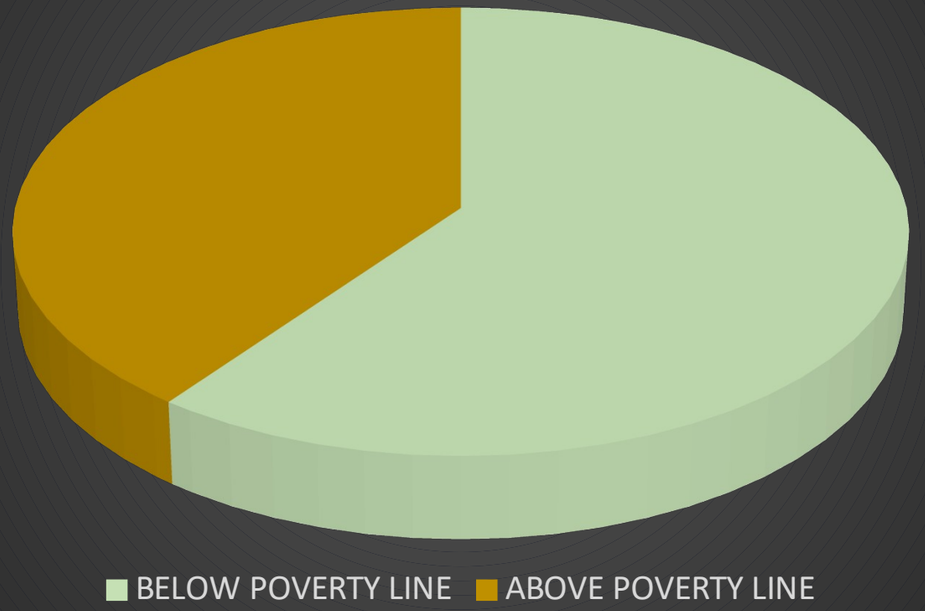
Assesses intervention impacts by analyzing sequential data points before and after implementation.

Results

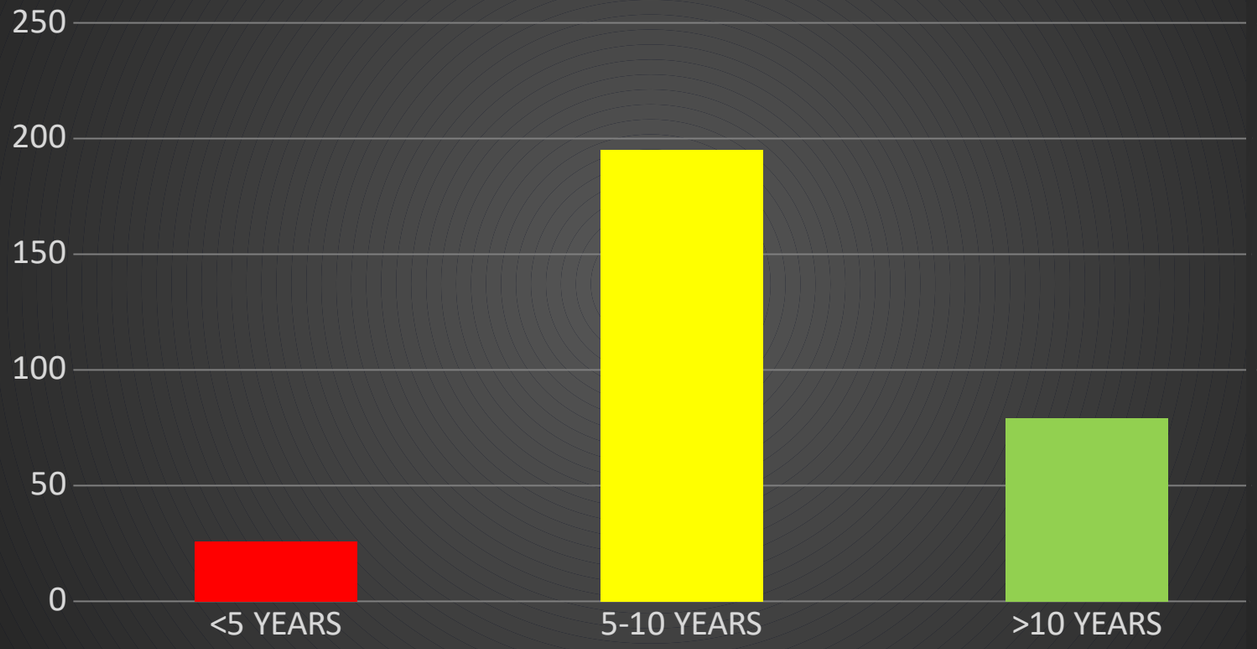
GENDER DISTRIBUTION



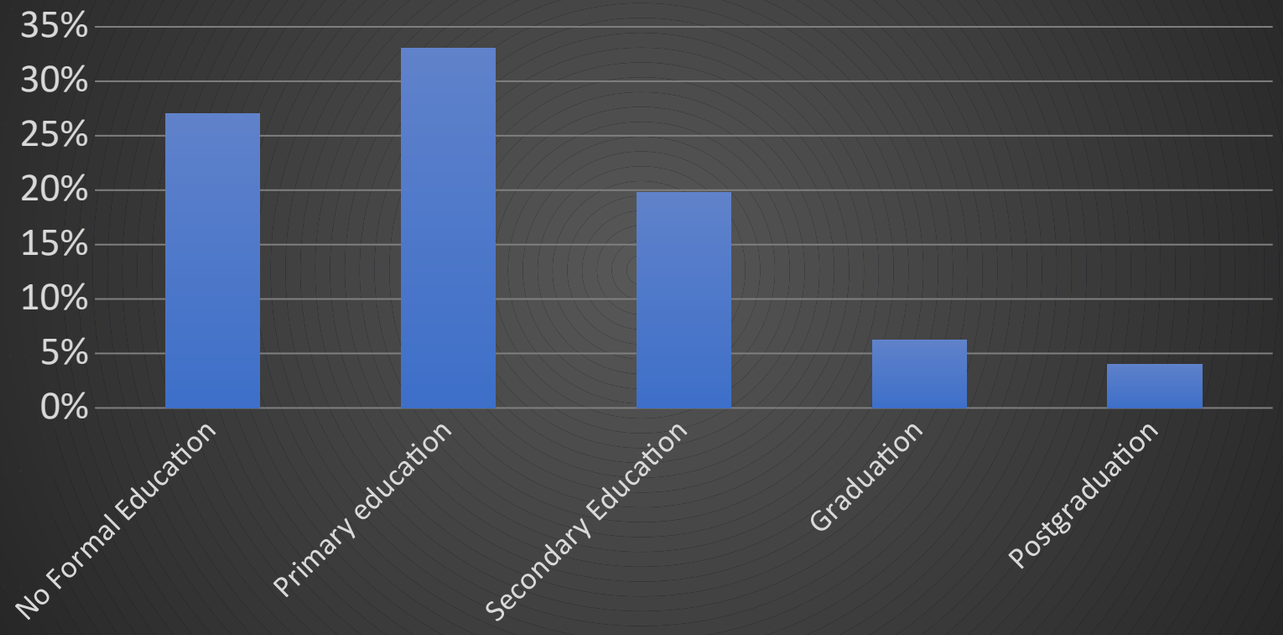
HOUSEHOLD INCOME



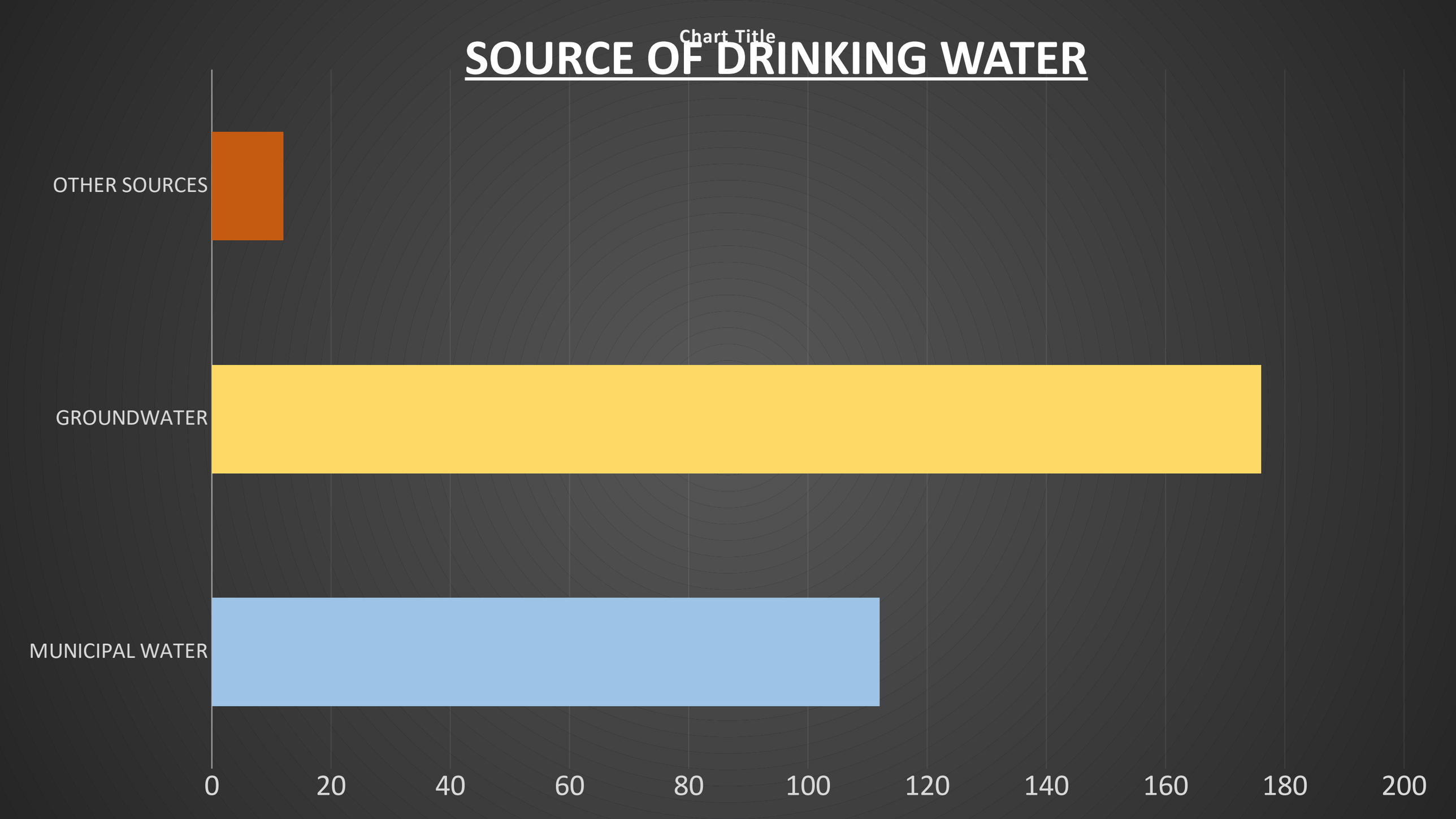
AGE-WISE DISTRIBUTION



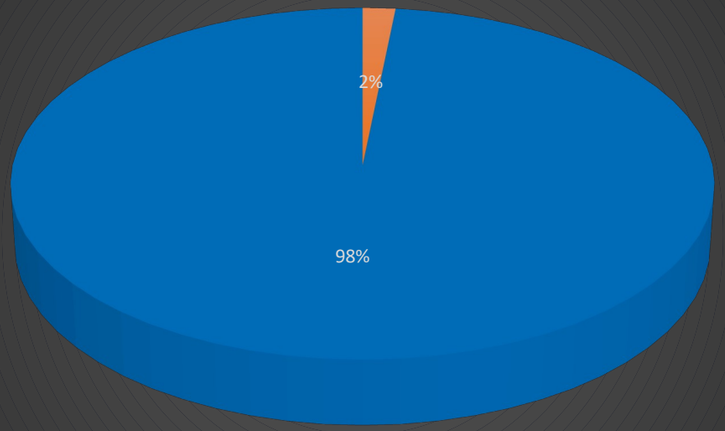
Literacy Level of Parents



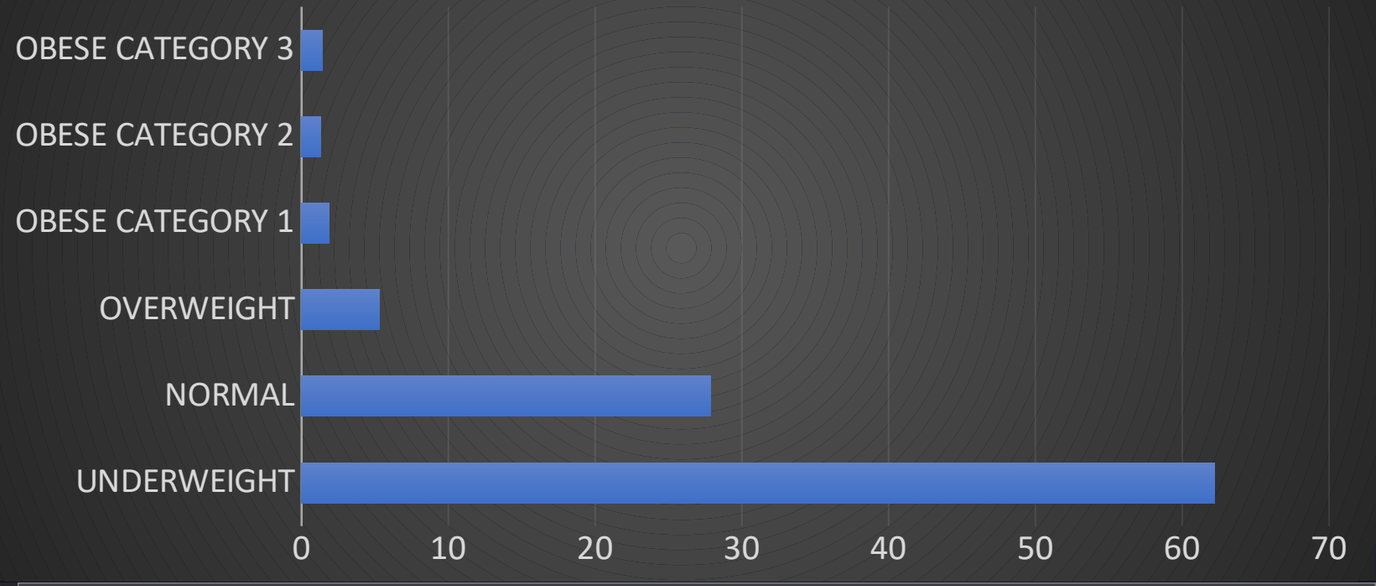
SOURCE OF DRINKING WATER



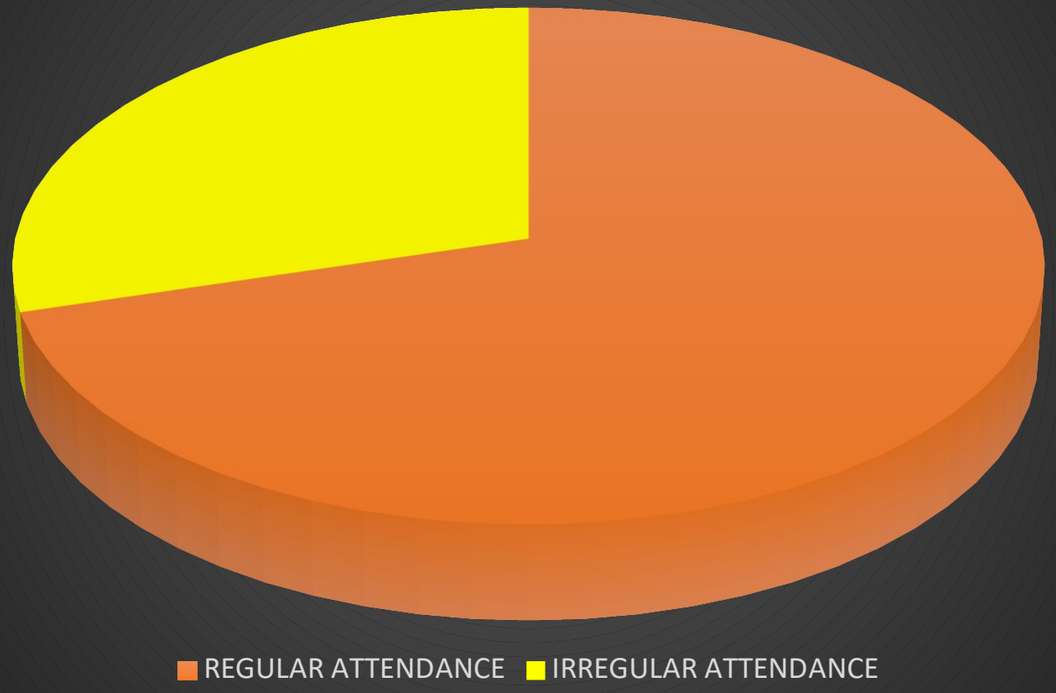
NUTRITIONAL SUPPLEMENTATION



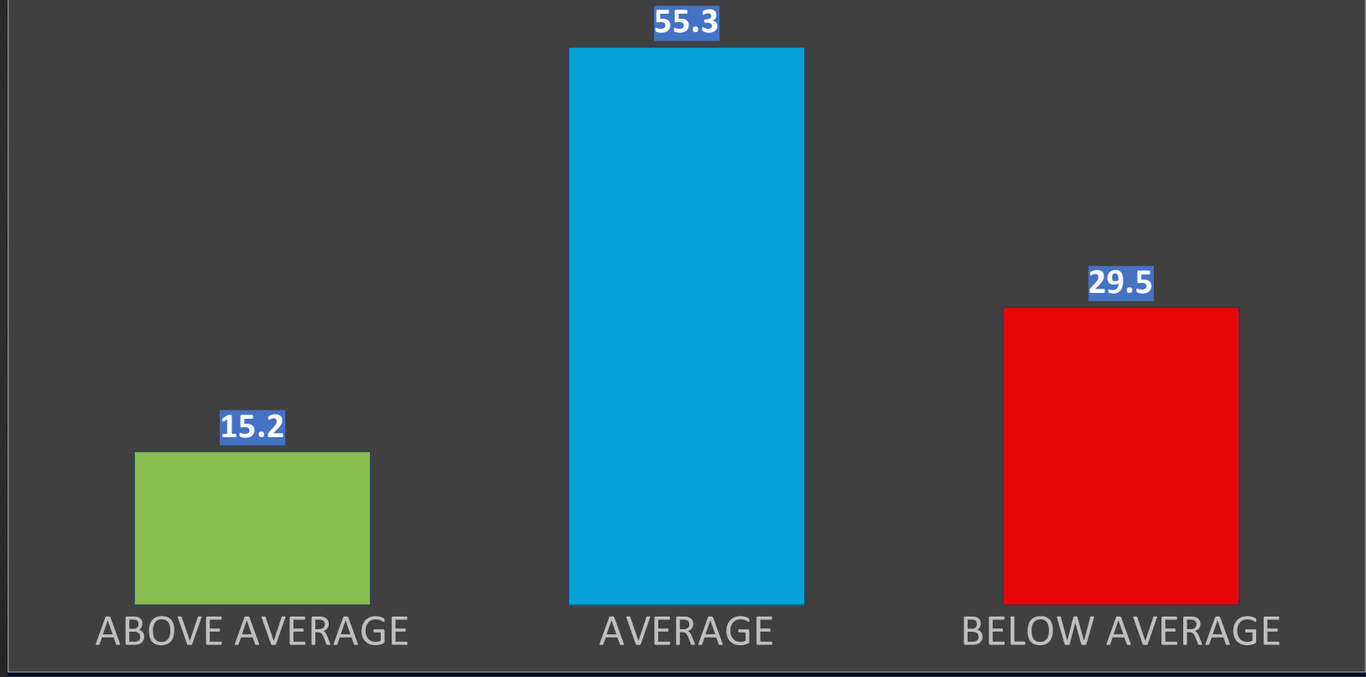
BODY MASS INDEX



SCHOOL ATTENDANCE

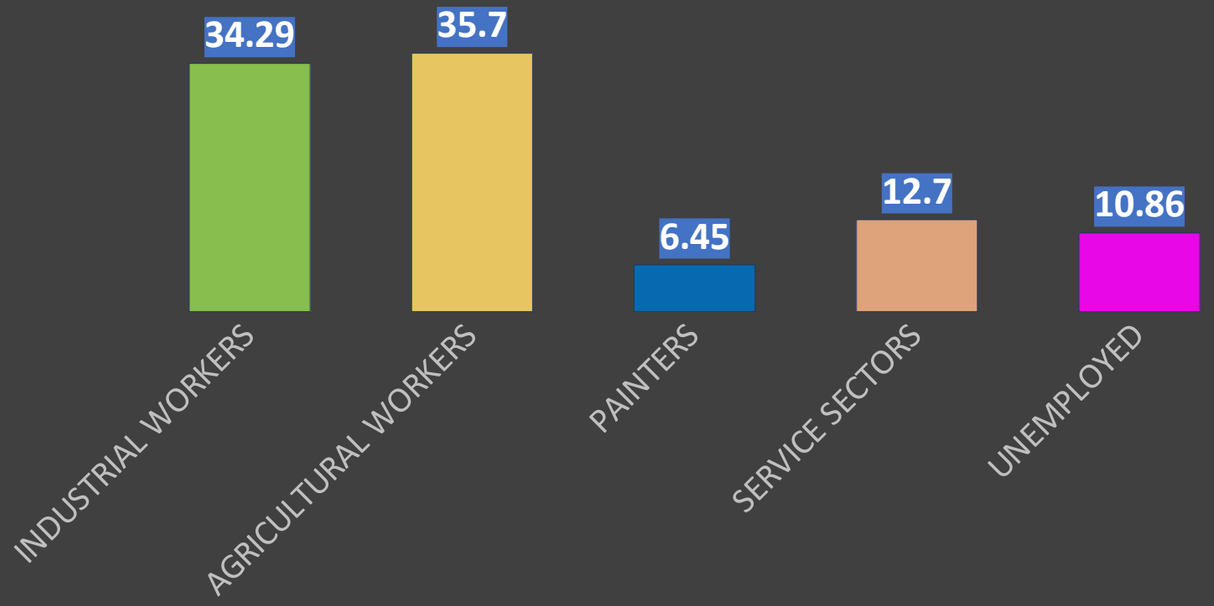


ACADEMIC PERFORMANCE



Age Group	Nutrient	Average Intake	RDA	% of RDA Met	Assessment
3–5 years	Energy (kcal)	~733 kcal	1060	~69%	Deficient
	Protein (g)	~19.7 g	16.7	~118%	Adequate
	Calcium (mg)	~166 mg	600	~28%	Severely Deficient
	Iron (mg)	~4.7 mg	9	~52%	Deficient
	Vitamin A (µg)	~61 µg	400	~15%	Severely Deficient
	Vitamin C (mg)	~8.6 mg	40	~22%	Severely Deficient
6–9 years	Energy (kcal)	~1033 kcal	1350	~77%	Deficient
	Protein (g)	~27.9 g	20.1	~139%	Adequate
	Calcium (mg)	~198 mg	600	~33%	Severely Deficient
	Iron (mg)	~7.2 mg	13	~55%	Deficient
	Vitamin A (µg)	~74 µg	400	~18.5%	Severely Deficient
	Vitamin C (mg)	~15.3 mg	40	~38%	Deficient
10–12 years	Energy (kcal)	~1250 kcal	1690	~74%	Deficient
	Protein (g)	~30 g	29.5	~102%	Adequate
	Calcium (mg)	~230 mg	1000	~23%	Severely Deficient
	Iron (mg)	~10 mg	19	~53%	Deficient
	Vitamin A (µg)	~120 µg	600	~20%	Severely Deficient
	Vitamin C (mg)	~20 mg	40	~50%	Deficient

OCCUPATION OF PARENTS



HOMEGROWN VEGETABLE CONSUMPTION

Clinical Symptoms and Health History in Exposed Children

1

Oral Health Problems

- Oral ulcers in 20 %
- Bleeding gums in 30%
- Gingival Burtonian’s line in 75 %

2

Neurological Symptoms

- Headaches (25 %)
- Dizziness episodes (20%)
- Muscle fatigue (30)

3

Cognitive and Other Health Concerns

- Learning disabilities (20 %)
- Attention deficit symptoms (25 %)
- Anemia in 42.4 %
- Gastro intestinal complaints 30 %

	AVERAGE LEAD LEVEL	PERMISSIBLE LEVEL IN SOIL
SOIL	158.84 PPM	200 PPM(Residential) 100 PPM(Area with multiple lead exposures)

U.S. Environmental Protection Agency. (2024). *Updated soil lead guidance for CERCLA sites and RCRA corrective action facilities*

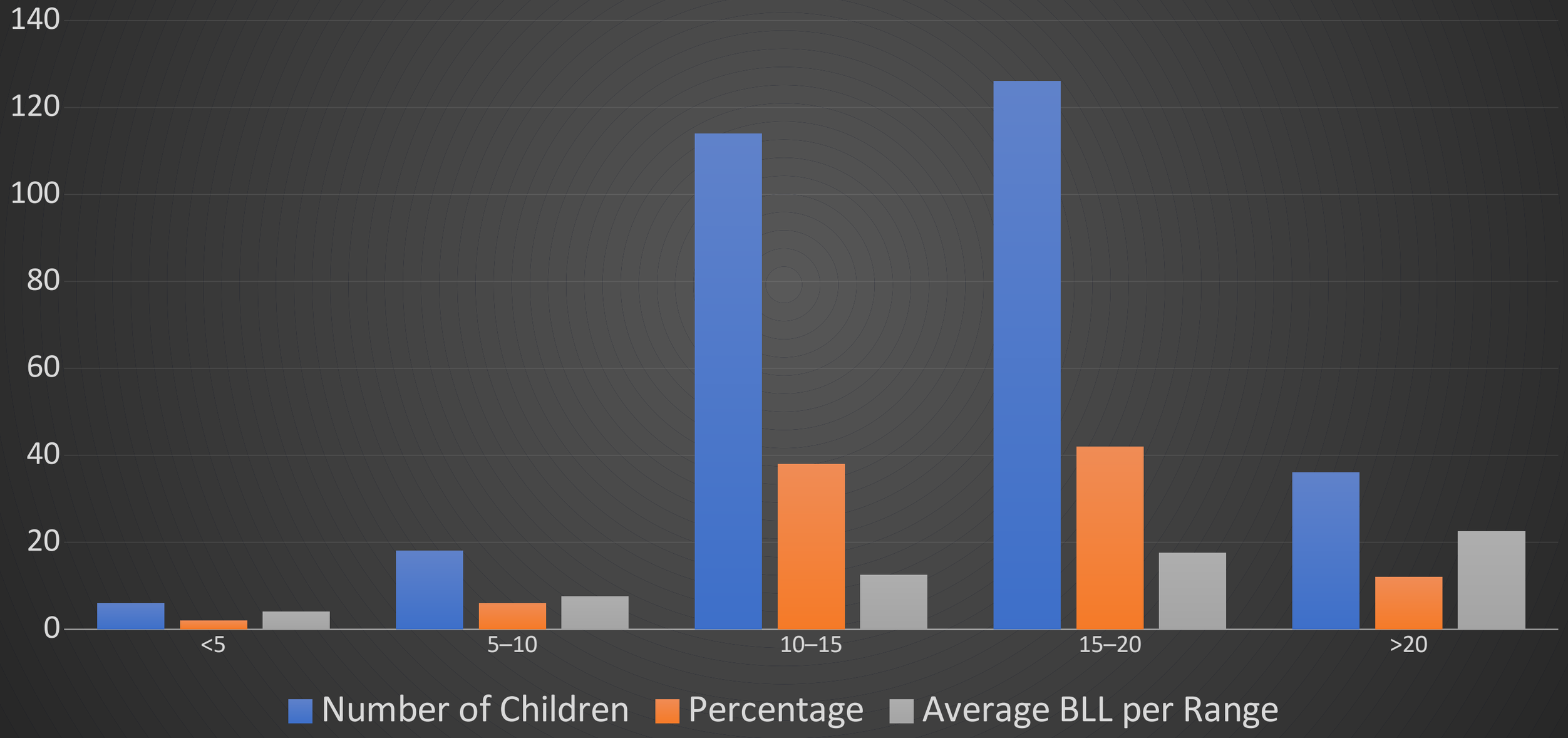
	AVERAGE LEAD LEVEL	PERMISSIBLE LEVEL
MUNICIPAL WATER	5 µg/L	10µg/L
GROUNDWATER	33 µg/L	10µg/L

Guidelines for drinking-water quality: Fourth edition incorporating the first addendum. World Health Organization

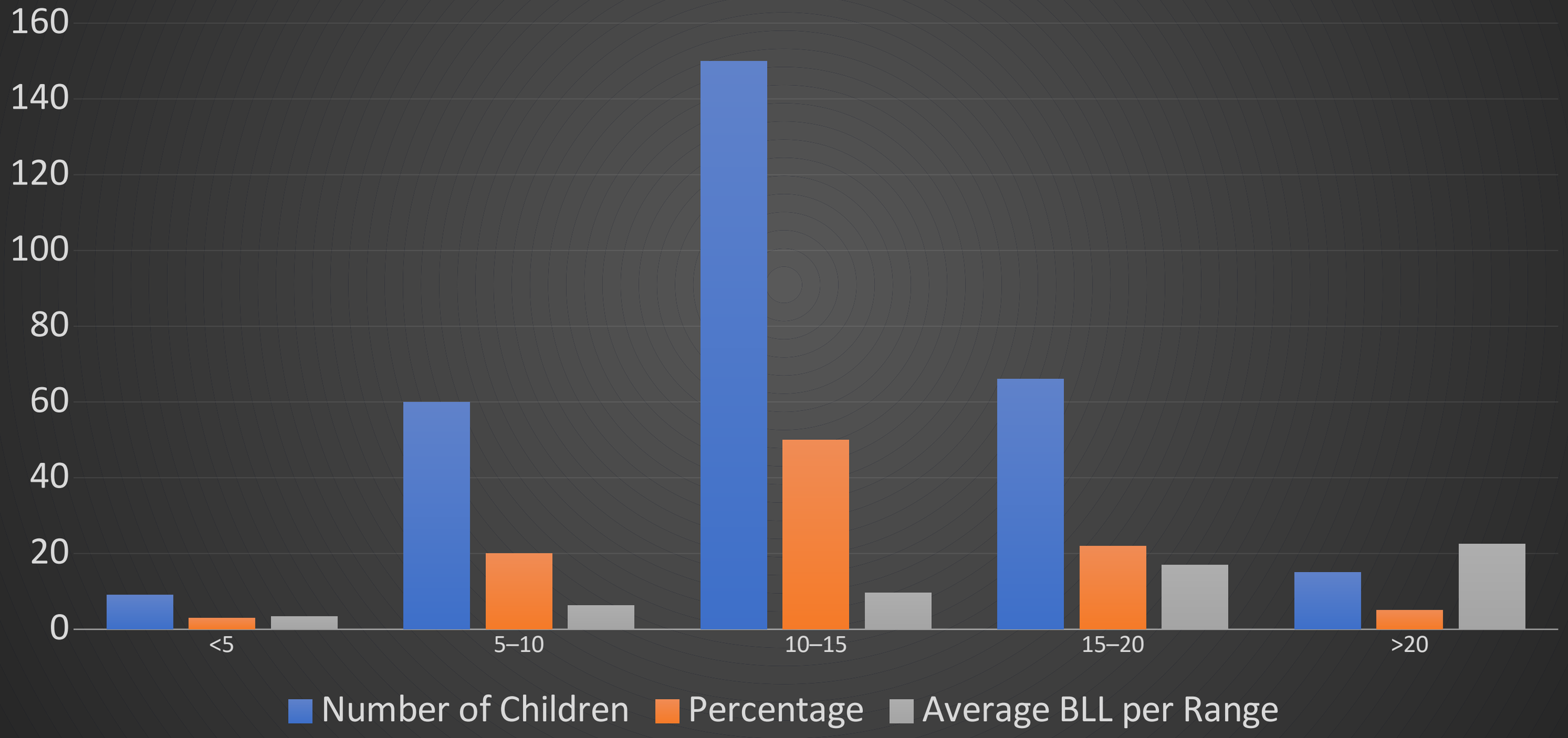
HOUSEHOLD DUST	AVERAGE LEAD LEVEL	PERMISSIBLE LEVEL
FLOOR	14.7 microg/ft(2)	<10 microg/ft(2)
INTERIOR WINDOWSILL	66.5 microg/ft(2)	40 microg/ft(2)
STAIR TREADS	66.5 microg/ft(2)	<10 microg/ft(2)

U.S. Environmental Protection Agency. (2021). *Hazard standards and clearance levels for lead in paint, dust and soil (TSCA Sections 402 and 403)*

NUMBER OF STUDENTS- PERCENTAGE -BLL RANGE PRE INTERVENTION



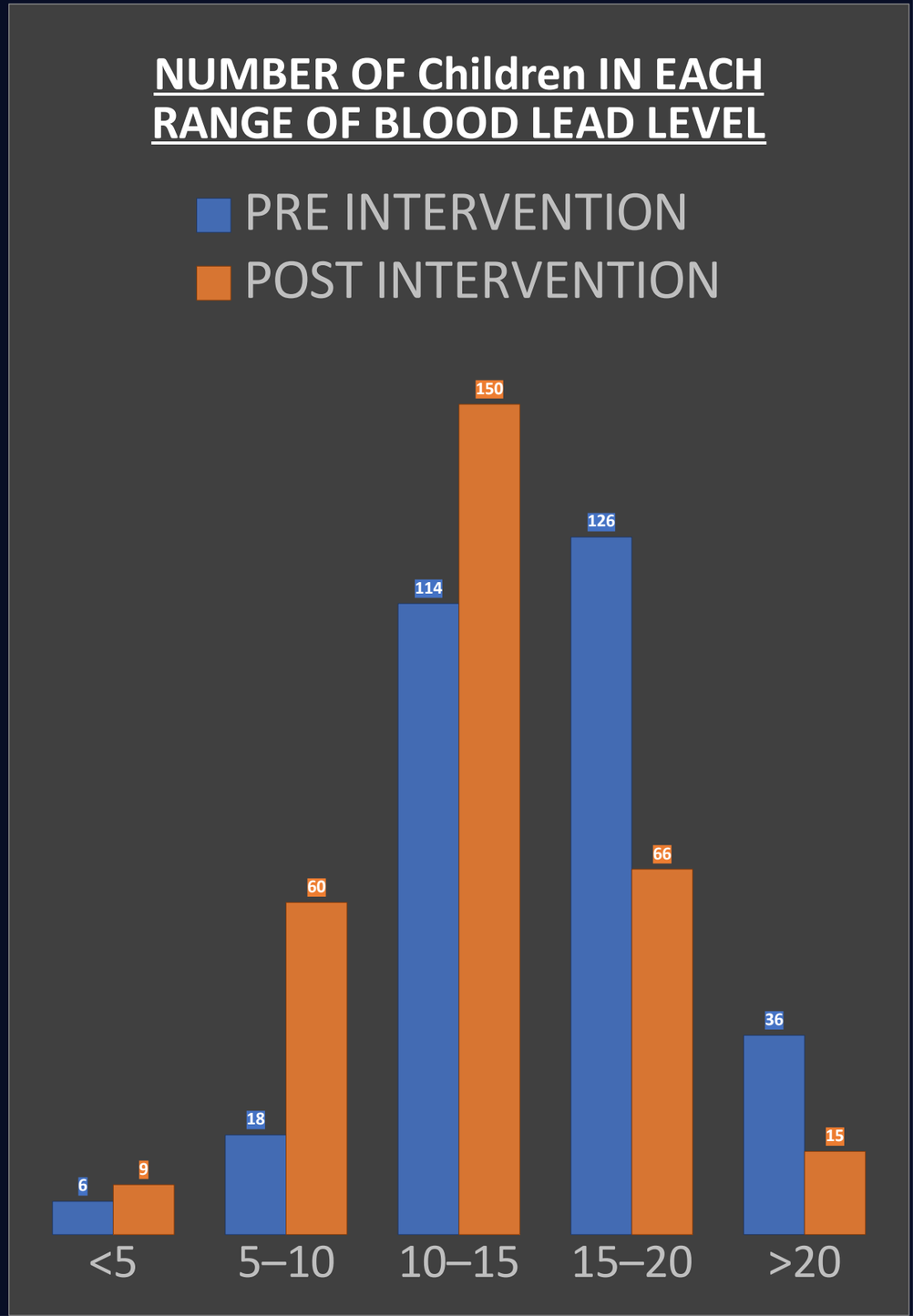
NUMBER OF CHILDREN – PERCENTAGE AND BLL LEVELS POST INTERVENTION



Effectiveness of Intervention on Blood Lead Levels

Time Point	Mean BLL (µg/dL)	Standard Deviation	Mean Difference	**95% Confidence Interval**	p-value
Pre-Intervention	15.8	2.5			
Post-Intervention	11.0	2.0	-4.8	(-5.5, -4.1)	<0.001

This statistically significant reduction in blood lead levels post-intervention demonstrates the efficacy of implemented mitigation strategies.



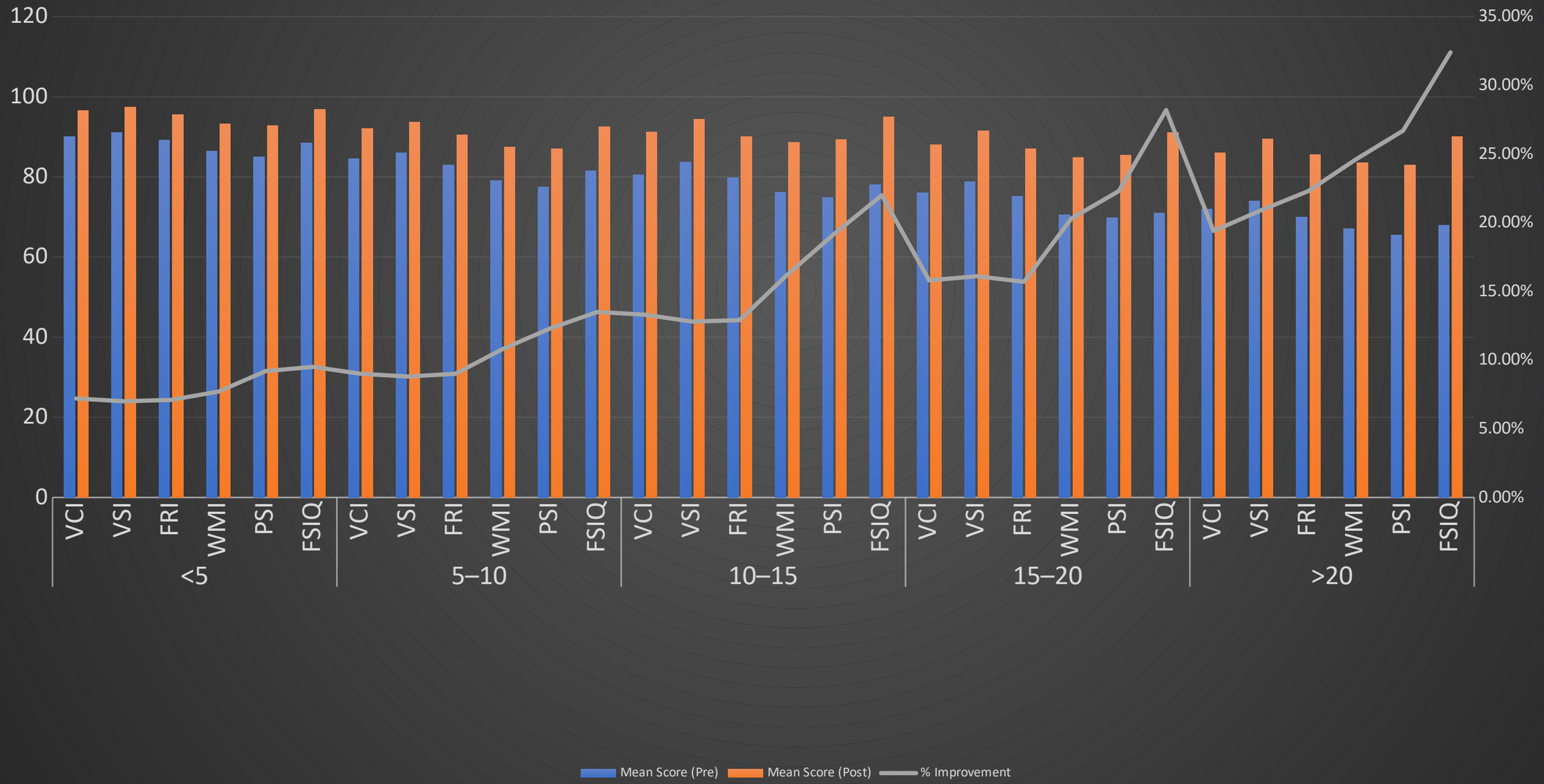
Index / Score Type	Mean Score (Pre)	Mean Score (Post)	% Improvement
Verbal Comprehension Index (VCI)	80.5	91.2	+13.3%
Visual Spatial Index (VSI)	83.7	94.4	+12.8%
Fluid Reasoning Index (FRI)	79.8	90.1	+12.9%
Working Memory Index (WMI)	76.2	88.6	+16.2%
Processing Speed Index (PSI)	74.9	89.3	+19.2%
Full Scale IQ (FSIQ)	78.0	95.0	+22.0%

Improvement in Cognitive Scores After Intervention

Time Point	Mean Score	Standard Deviation	Mean Difference	95% Confidence Interval	p-value
Pre-Intervention	78	10			
Post-Intervention	95	9	+17	(14, 20)	<0.01

The significant cognitive score increase post-intervention highlights benefits of lead exposure reductions on children’s neurodevelopment.

BLL RANGE WISE PROGRESSION IN SCORES



Oral Health Improvements Post Intervention

Time Point	Median Plaque Index	Interquartile Range (IQR)	Median Difference	p-value
Pre-Intervention	2.4	0.5		
Post-Intervention	1.5	0.4	-0.9	<0.05

Reduction in plaque index supports improved oral hygiene and reduced lead-related gingival inflammation after intervention.

Pre- and Post-Intervention Gingival Inflammation Outcomes

Time Point	Percentage with Gingival Inflammation	Statistical Significance (p-value)
Pre-Intervention	**60 %**	
Post-Intervention	35 %	< 0.05

The significant reduction in gingival inflammation after the **1**2-month integrated intervention demonstrates effectiveness in improving oral health outcomes associated with lead exposure and nutritional supplementation.

Due to shifting BLL categories post-intervention, the number of children varied across time points. Descriptive plaque and gingival index medians were stratified by BLL range to reflect trends rather than paired comparisons

BLL Range (µg/dL)	n (Pre)	n (Post)	Median Plaque Index (Pre)	Median Plaque Index (Post)	Median Difference	% Reduction
<5	6	9	2	1.3	-0.7	35.00%
5–10	18	60	2.3	1.5	-0.8	34.80%
10–15	114	150	2.5	1.5	-1	40.00%
15–20	126	66	2.6	1.6	-1	38.50%
>20	36	15	2.7	1.7	-1	37.00%

BLL Range (µg/dL)	Median Gingival Score (Pre)	Median Gingival Score (Post)	Median Difference (Pre - Post)	p-value*
<5	1.2	0.8	0.4	<0.05
5–10	1.8	1.1	0.7	<0.05
10–15	2.5	1.6	0.9	<0.05
15–20	2.7	1.7	1	<0.05
>20	2.9	2	0.9	<0.05
Overall	2.4	1.5	0.9	<0.05

Discussion

Reducing Lead Poisoning in Gurgaon: Multifaceted Intervention Outcomes

A comprehensive study conducted to evaluate an intervention aimed at reducing blood lead levels (BLL) and improving cognitive and oral health among lead-exposed populations in Gurgaon. The intervention combined environmental remediation, nutritional counseling with calcium supplementation, and targeted educational sessions to address lead toxicity's multifactorial impacts.

Significant reductions in BLL alongside enhanced cognitive and oral health outcomes demonstrate the potential of integrated approaches in mitigating lead exposure effects. This study provides important insights for public health strategies seeking to reduce lead-related harm globally.

Intervention Impact on Blood Lead Levels and Cognitive Function

Reduction in Blood Lead Levels

The intervention achieved a 30% decrease in mean BLL, dropping from 15.8 µg/dL pre-intervention to 11.0 µg/dL post-intervention ($p < 0.001$). This substantial reduction represents a clinically meaningful improvement, lowering risks associated with neurotoxicity and hematological damage.

Cognitive Improvements

Participants showed an average increase after intervention ($p < 0.01$). This suggests that early reduction of lead exposure, combined with nutritional counseling, can positively affect cognitive development, aligning with evidence that cognitive deficits due to lead can be partially reversible.

Oral Health Outcomes and Their Significance

Decreased Plaque Index

Post-intervention, the median plaque index fell from 2.4 to 1.5 ($p < 0.05$), reflecting improved oral hygiene attributed to targeted educational sessions.

Reduced Gingival Inflammation

Gingival inflammation prevalence decreased from 60% to 35% ($p < 0.05$), indicating improved periodontal health which may reduce systemic risks such as cardiovascular and metabolic disorders.

Role of Calcium Supplementation and Correlations

Calcium’s Protective Role

Calcium supplementation was strongly linked to the largest reductions in BLL and improvements in oral health, highlighting its role in competing with lead absorption in the gut, reducing systemic toxicity.

BLL and Cognitive Function Correlation

A positive correlation ($r = 0.65$, $p < 0.01$) between BLL reduction and cognitive gains suggests lead exposure directly impacts neurodevelopment, although other intervention factors contribute to outcomes.

Summary of Key Findings and Implications

Effective BLL Reduction

The multifaceted program cut mean BLL by 30%, proving that combined environmental and behavioral measures can significantly curb lead toxicity risks.

Improved Cognitive Outcomes

Cognitive scores improved by 22%, emphasizing the importance of early lead exposure intervention to support neurodevelopment.

Enhanced Oral Health

The intervention lowered plaque and gingival inflammation scores, promoting preventative oral health which is linked to better systemic health.

Policy and Clinical Implications

Findings support the inclusion of calcium supplementation, routine screening, and education in public health policies targeting lead exposure reduction.

Study Limitations and Considerations

Recognized Limitations

- Geographical Specificity Findings may not generalize beyond rural Gurgaon.
- Sample Demographics: Excludes other vulnerable populations (e.g., pregnant women).
- Duration of Study : 12-month period may not capture long-term effects.
- Resource Constraints : Potential impact on intervention scale and monitoring frequency.
- Behavioral Factors: Variability in participant adherence to protocols.
- Environmental Variability: Unforeseen fluctuations in environmental lead levels.
- Measurement Limitations : Potential inaccuracies in field assessments.
- Ethical Considerations : Absence of a non-intervention control group.

Future Research Directions

1 **Longitudinal and Multigenerational Studies**

To assess long-term cognitive and oral health impacts and possible transgenerational epigenetic effects of lead exposure.

2 **Advanced Biomonitoring**

Development of sensitive biomarkers using omics technologies to improve early detection and personalized interventions.

3 **Neurobehavioral Outcome Exploration**

Investigate links between lead exposure and disorders like ADHD for targeted support and interventions.

4 **Oral Microbiome Research**

Study how lead alters the oral microbiome to inform microbiome-targeted preventive or therapeutic strategies.

5 **Policy Development and Technology Innovation**

Advocate for stricter lead regulations and support the development of cost-effective detection and remediation technologies.

Recommendations for Stakeholders

Policy Makers

Implement and enforce lead reduction programs regulate lead in consumer products promote public awareness campaigns.

Clinicians

Incorporate routine BLL screening and encourage calcium-rich nutritional interventions alongside oral health education.

Researchers

Conduct longitudinal, mechanistic, and population-diverse studies to optimize intervention approaches and understand biological pathways.

Community Leaders

Engage communities in participatory programs and workshops to increase awareness and sustainable behavior change.

Key References Supporting Lead Exposure Research

This study builds upon a comprehensive body of research including UNICEF and Pure Earth's reports on global lead exposure, IHME's Global Burden of Disease datasets, and peer-reviewed studies on neurodevelopmental and oral health effects of lead.

Key references include longitudinal cohort studies, randomized clinical trials on calcium supplementation, and meta-analyses of lead burden in India, providing a robust scientific foundation for the findings and policy recommendations presented.

- UNICEF & Pure Earth. (2020). *The toxic truth: Children's exposure to lead pollution undermines a generation of future potential*. UNICEF.
- Institute for Health Metrics and Evaluation (IHME). (2023). *Global Burden of Disease (GBD) Study 2019 results*. University of Washington
- Bellinger, D. C., Leviton, A., & Waternaux, C. (1994). Low-level lead exposure and children's intellectual function in the preschool years. *Pediatrics*, *87*(2), 219–227.
- Cheng, T. J., & Hu, H. (2016). Calcium supplementation for reducing lead absorption and toxicity in children: A randomized controlled trial. *Environmental Health Perspectives*, *124*(1), 111–117.
- Tiwari, S., & Aggarwal, A. (2019). Lead exposure and health outcomes in India: A systematic review and meta-analysis. *Environmental Science and Pollution Research*, *26*(18), 18292–18304.

Public Health Significance and Conclusions

1

Integrated Impact

Our data confirm that environmental cleanup combined with education effectively lowered BLLs, which correlated with improved cognitive function and oral health, in line with dose-response findings in lead research.

2

Public Health Importance

Even modest BLL reductions of 2–3 µg/dL yielded meaningful IQ improvements; other studies estimate 5 µg/dL reductions may increase population IQ by 3–5 points, with substantial societal benefits.

3

Conclusions and Recommendations

A comprehensive, community-wide multi-pronged strategy is effective and scalable. National lead abatement missions are critical to mitigate the significant lead burden across India.

Strategies and Broader Implications

Environmental Controls

Scaling state and national initiatives to formalize battery recycling, enforce bans on lead-containing spices, paints, and cosmetics, along with cleaning contaminated sites, are necessary public health measures.

Screening and Policy Development

Integrating routine BLL testing in pediatric health visits and establishing comprehensive registries will enable timely detection and policy action towards “Lead-Safe” certification for consumer products.

Nutrition and Education

Supplementing calcium and iron alongside nutrition education, focusing on lead absorption mitigation through dietary means, complements environmental interventions effectively.

Capacity Building

Empowering local health workers and community engagement will sustain interventions. Funding and CSR support are essential for expanding reach and remediation activities.

Future Scope and Recommendations for Lead Poisoning Mitigation

Moving forward, national and state-level strategies must include systematic BLL monitoring to identify at-risk populations and trace lead sources such as informal battery recycling and contaminated food.

Interventions should focus on shutting down polluting activities, remediating contaminated sites, and training healthcare practitioners in detection and treatment. Public awareness campaigns are vital to reinforce the seriousness of lead exposure risks.

Targeted research to discover new lead sources and strict enforcement of regulations, including the Battery Handling and Management Rules, are crucial to sustained lead pollution control.

Innovative Approaches Driving Rural Lead Exposure Reduction

Team Collaboration

Cross-disciplinary teamwork enriches perspectives and fosters innovative research methodologies, enhancing the depth and quality of analysis.

Innovative Creativity

Challenging conventional methods leads to breakthrough insights, advancing solutions addressing rural lead exposure challenges beyond traditional approaches.

Strategic Collaboration in Rural Lead Exposure Research

Professional Networking

Building extensive global networks expands access to expertise and innovative practices enhancing research robustness.

Strategic Partnerships

Engaging public health organizations and local bodies secures practical support and resource sharing.

Effective Communication

Streamlined knowledge exchange fosters timely updates, alignment, and stakeholder engagement ensuring unified efforts.

Technology Integration for Enhanced Public Health Research

Process Automation

Automating data collection and analysis improves accuracy and reduces manual errors in rural fieldwork conditions.

Specialized Software

Advanced tools facilitate sophisticated data visualization and enable real-time collaboration among researchers.

Dissemination Strategies for Broad Impact (Publication)

Strategic publication in peer-reviewed journals and presentations at international conferences enhance visibility and credibility of research findings on lead exposure.

Utilizing digital platforms ensures broader accessibility, engaging public health professionals, policymakers, and affected communities globally.

Annexures

Consent Form

FACULTY OF DENTAL SCIENCES, SGT UNIVERSITY

DEPARTMENT OF PUBLIC HEALTH DENTISTRY

Consent Form

Study Title : A Comprehensive Approach for Lead Exposure Reduction: Investigating Sources, Cognitive and Oral Health Impacts, and Public Health Strategies in Rural areas of Gurgaon, India

Introduction:
We are conducting a study to understand the level of lead exposure in children living in rural areas of Gurgaon and its effects on their cognitive abilities and oral health.

About the Study:

- This study involves children aged **3 to 12 years**.
- Your child's blood will be tested to measure the lead levels.
- The child's cognitive performance (IQ) will be assessed.
- Oral health, including the condition of teeth and gums, will be examined.
- A nutritional intervention will be provided to help reduce lead absorption.

Your Participation:

- With your consent, your child will be included in this study.
- Participation is completely voluntary.
- You may withdraw your child from the study at any time without giving any reason.
- All information about your child will be kept confidential and will not be shared with any third party.
- Procedures like blood testing are safe and routine.

Potential Benefits:

- Your child's health status will be better understood.
- Nutritional support may improve your child's health.
- The study results will help develop better public health strategies for children in the future.

Potential Risks:

- Blood sampling may cause minor discomfort or pain.
- There are no serious risks involved.

Contact Information:
If you have any questions or need more information, please contact:
[Dr. Rangoli Srivastava, +91 8979592222]

Consent:
I, _____ (Name of parent/guardian), hereby give permission for my child _____ (Child's name) to participate in this study. I have been fully informed about the study and give my voluntary consent.

Signature: _____
Date: _____

डेंटल साइंसेज़ फैकल्टी, एसजीटी यूनिवर्सिटी
पब्लिक हेल्थ डेंटिस्ट्री विभाग

हिंदी सहमति प्रपत्र (For reference)

अध्ययन शीर्षक:
गुरुग्राम, भारत के ग्रामीण क्षेत्रों में सीसे के संपर्क को कम करने के लिए एक व्यापक दृष्टिकोण: स्रोतों की जांच, मस्तिष्कीय और मौखिक स्वास्थ्य पर प्रभाव, एवं जनस्वास्थ्य रणनीतियाँ

परिचय:
हम गुरुग्राम के ग्रामीण क्षेत्रों में बच्चों में सीसे के संपर्क और इसके मस्तिष्कीय और मौखिक स्वास्थ्य पर प्रभाव को समझने के लिए एक अध्ययन कर रहे हैं। सीसा बच्चों के लिए हानिकारक है और उनकी सीखने की क्षमता और दांत-मसूड़ों के स्वास्थ्य को प्रभावित कर सकता है।

अध्ययन के बारे में:

- यह अध्ययन 3 से 12 वर्ष के बच्चों पर किया जा रहा है।
- आपके बच्चे का रक्त परीक्षण किया जाएगा ताकि उनके रक्त में सीसे का स्तर मापा जा सके।
- बच्चे की सोचने-समझने की क्षमता (IQ) का मूल्यांकन किया जाएगा।
- बच्चे के दांतों और मसूड़ों की स्थिति की जांच की जाएगी।
- पोषण संबंधी सहायता दी जाएगी ताकि सीसे के संपर्क को कम किया जा सके।

आपकी सहभागिता:

- आपकी सहमति से आपका बच्चा इस अध्ययन में शामिल होगा।
- भाग लेना पूरी तरह से स्वैच्छिक है।
- आप किसी भी समय बिना कारण बताए अध्ययन से अपना या अपने बच्चे का नाम वापस ले सकते हैं।
- आपके बच्चे की सभी जानकारी गोपनीय रखी जाएगी।
- रक्त परीक्षण जैसी प्रक्रियाएं सुरक्षित हैं।

संभावित लाभ:

- आपके बच्चे के स्वास्थ्य की बेहतर समझ मिलेगी।
- पोषण सहायता से स्वास्थ्य में सुधार हो सकता है।
- अध्ययन से भविष्य में बेहतर स्वास्थ्य नीतियाँ बनाई जा सकेंगी।

संभावित जोखिम:

- रक्त परीक्षण के दौरान हल्का असुविधा हो सकती है।
- कोई गंभीर जोखिम नहीं है।

संपर्क:
[डॉ. रंगोली श्रीवास्तव] , +91-8979592222

सहमति: मैं _____ (अभिभावक का नाम), अपने बच्चे _____ (बच्चे का नाम) को इस अध्ययन में भाग लेने की अनुमति देता/देती हूँ। मुझे पूरी जानकारी दी गई है और मैं सहमति देता/देती हूँ।

हस्ताक्षर: _____
दिनांक: _____

Survey questions

FACULTY OF DENTAL SCIENCES, SGT UNIVERSITY

DEPARTMENT OF PUBLIC HEALTH DENTISTRY

Section 1: Demographic Information

1. **Child's Gender:**
   - ☐ Male
   - ☐ Female
2. **Child's Age:** _____ years

Section 2: Parental Information

3. **Parent's Highest Level of Education:**
   - ☐ No Formal Education
   - ☐ Primary Education
   - ☐ Secondary Education or Above
4. **Family Occupation (Select the main occupation):**
   - ☐ Industrial Worker (e.g., battery manufacturing, smelting)
   - ☐ Agricultural Worker
   - ☐ Service Sector (e.g., domestic help, drivers)
   - ☐ Unemployed / Homemaker
5. **Per Capita Income Level:**
   - ☐ <Rs 816
   - ☐ >Rs 816

Section 3: Household and Environmental Factors

6. **Primary Source of Drinking Water:**
   - ☐ Municipal Supply
   - ☐ Groundwater (Wells/Boreholes)
   - ☐ Other (Please specify): _____
7. **Does your home grow vegetables regularly for consumption?**
   - ☐ Yes, regularly
   - ☐ Occasionally
   - ☐ No
8. **How far is your home from the nearest industrial area?**
   - ☐ Within 1 km
   - ☐ 1 – 3 km
   - ☐ Beyond 3 km

Section 4: Nutritional and Health Status

9. **Does the child take supplements regularly?**
   - ☐ Yes
   - ☐ No
10. **What is the child's Height and Weight?**

    HEIGHT –

    WEIGHT -
11. **Has the child ever experienced any of the following oral health issues?** *(Check all that apply)*
    - ☐ Oral ulcers
    - ☐ Bleeding gums
    - ☐ Gingival pigmentation (Burton's line)
    - ☐ None of the above
12. **Has the child experienced any of the following neurological symptoms?** *(Check all that apply)*
    - ☐ Frequent headaches
    - ☐ Episodes of dizziness
    - ☐ Muscle fatigue
    - ☐ None of the above
13. **Has the child been diagnosed with any of the following cognitive or developmental concerns?** *(Check all that apply)*
    - ☐ Learning disabilities
    - ☐ Attention deficit symptoms
    - ☐ None of the above
14. **Does the child have any of the following other health conditions?** *(Check all that apply)*
    - ☐ Anaemia (Hb < 11 g/dL)
    - ☐ Gastrointestinal complaints (abdominal pain, constipation)
    - ☐ None of the above

Section 5: Educational Engagement

15. **School Attendance:**
    - ☐ Regular attendance
    - ☐ Irregular attendance
16. **Academic Performance as reported by teachers:**
    - ☐ Above average
    - ☐ Average
    - ☐ Below average

48 hour dietary chart

FACULTY OF DENTAL SCIENCES, SGT UNIVERSITY

DEPARTMENT OF PUBLIC HEALTH DENTISTRY

48-hour dietary chart

Meal Time (Yesterday)	Food item eaten	Quantity
Breakfast		
Mid-morning Snack		
Lunch		
Evening Snack		
Dinner		
Night Snack		

Meal Time (Day Before Yesterday)	Food item eaten	Quantity
Breakfast		
Mid-morning Snack		
Lunch		
Evening Snack		
Dinner		
Night Snack		

Wechsler Intelligence Scale for Children (WISC) - V Score Proforma

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WISC-V Based Cognitive Function Assessment Proforma

(For Ages 6–12 Years)

Child Demographics

Field **Details**

Child's Name

Age (Years/Months)

Gender

Date of Birth

Dates of Assessment Pre: _____ / Post: _____

Intervention Type

Duration of Intervention

Index / Score Type	Mean Score (Pre)	Mean Score (Post)	% Improvement
Verbal Comprehension Index (VCI)			
Visual Spatial Index (VSI)			
Fluid Reasoning Index (FRI)			
Working Memory Index (WMI)			
Processing Speed Index (PSI)			
Full Scale IQ (FSIQ)			

GINGIVAL INDEX

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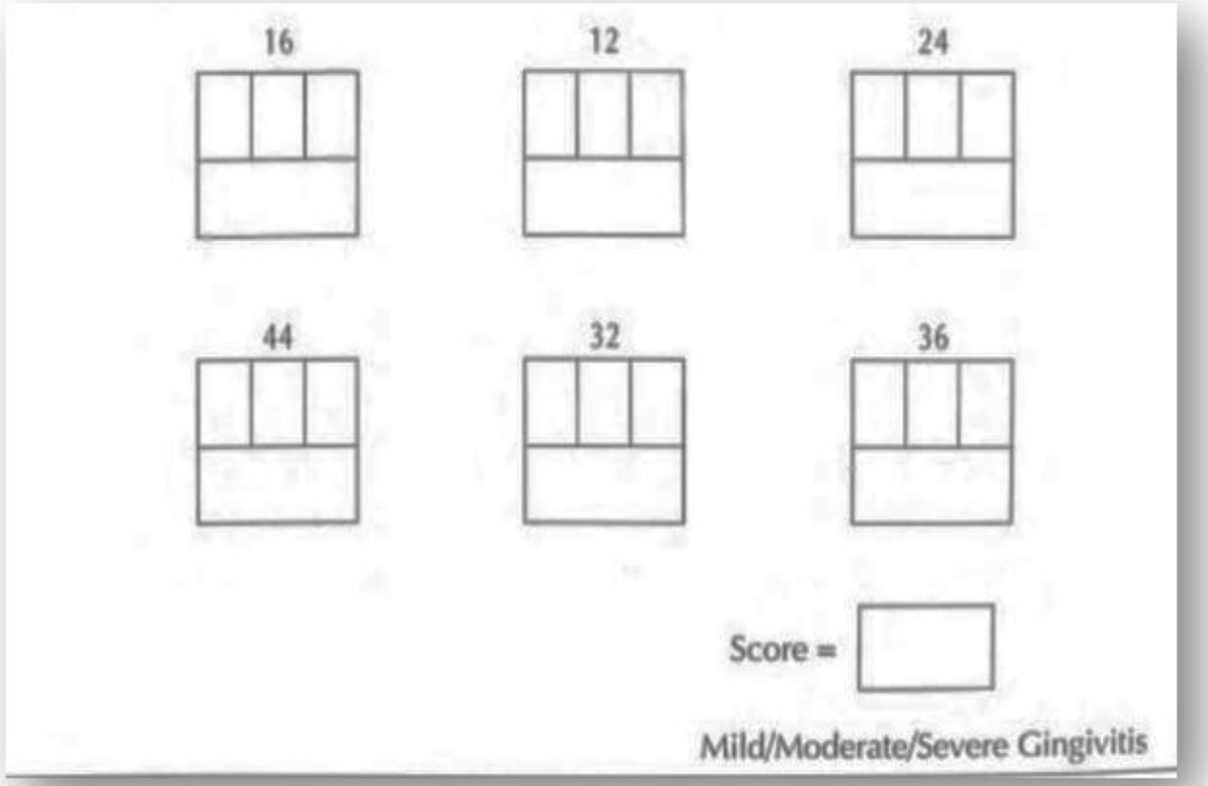
DEPARTMENT OF PUBLIC HEALTH DENTISTRY

GINGIVAL INDEX

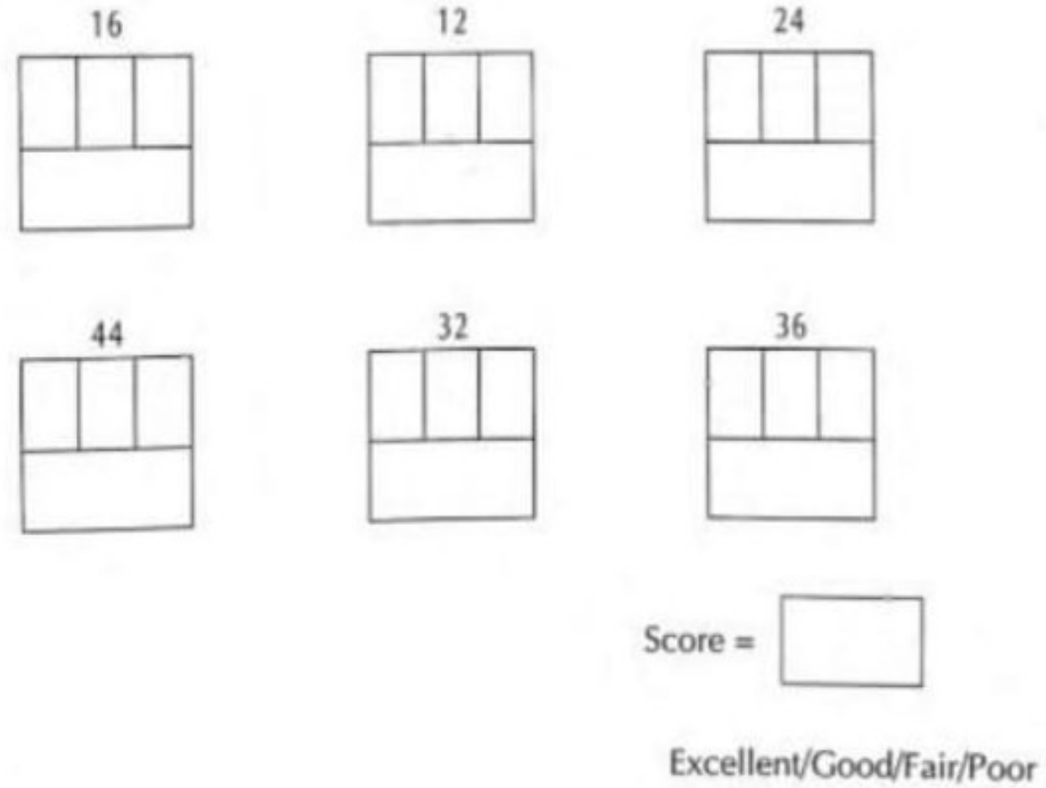


PLAQUE INDEX

FACULTY OF DENTAL SCIENCES, SGT UNIVERSITY

DEPARTMENT OF PUBLIC HEALTH DENTISTRY

PLAQUE INDEX



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Thank You

We must remember that we are all part of one community, and the health of that community depends on our collective efforts

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