Study to
Ascertain the Impact of the achievement of Open Defecation Free (ODF) status, on the incidence of Environmental Contamination in Odisha, Bihar and West Bengal

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List of Abbreviations and Acronyms Used

APHA	:	American Public Health Association
As	:	Arsenic
AWWA	:	American Water Works Association
BIS	:	Bureau of Indian Standard
CAOT	:	Community and Other Toilets
cfu	:	Colony Forming Units
Cl	:	Chloride
DNA	:	Deoxyribonucleic acid
EC	:	Electrical Conductivity
FIB	:	Faecal Indicator Bacteria
GPS	:	Global Positioning System
HH	:	Households
HuBac	:	Human-specific Bacteria
IS	:	Indian Standard
ISO	:	International Organization for Standardization
MDM	:	Midday Meal
MDWS	:	Ministry of Drinking Water and Sanitation
MPN	:	Most Probable Number
MST	:	Microbial Source Tracking
NA	:	Not Applicable/ Not Available
NTU	:	Nephelometric Turbidity Unit
ODF	:	Open Defecation Free
RuBac	:	Ruminant-specific Bacteria
SBM-G	:	*Swachh Bharat* Mission-*Gramin*
SDGs	:	Sustainable Development Goals
SRI	:	Shriram Institute for Industrial Research
TDS	:	Total Dissolved Solids
TKN	:	Total Kjeldahl Nitrogen
UNICEF	:	United Nations Children's Fund
WEF	:	World Environment Federation

1. Introduction

1.1 Background

The Sustainable Development Goals (SDGs) have committed the international community to expand international cooperation and capacity building on water and sanitation related activities and programmes, and also to support local communities in improving water and sanitation management. Through Goal 6, the countries of the world have resolved to achieve universal access to safe drinking water and adequate sanitation and hygiene to all by 2030. The aim is to ensure the consumption of safe drinking water, practice safe sanitation and hygiene, resulting in lower exposure to a contaminated environment, resulting in lower morbidity and mortality, especially amongst children[1].

The *Swachh Bharat Mission* was launched by the Government of India on 2nd October, 2014 to achieve the vision of *"Swachh Bharat"* by 2nd October 2019. The *Swachh Bharat Mission Gramin*-SBM (G) endeavours to accelerate rural sanitation coverage, reduce open defecation and improve management of solid and liquid wastes in rural areas. The implementation of SBM (G) is the responsibility of the Ministry of Drinking Water and Sanitation[2]. The MDWS, while issuing guidelines for ODF verification[3] stressed on "safe technology option which aimed at no contamination of surface soil, ground water or surface water; excreta management inaccessible to flies or animals; no human handling of fresh excreta; and freedom from odour and unsightly condition". Over the past 4 years, over 92 million new households have received access to household toilets, and by the end of the SBM G programme, all 16.5 million rural households will have such access. However, the issue is of usage, and thus the goal is to create Open Defecation Free (ODF) communities and villages, with no one defecating in the open.

The status of ODF villages published on the website of MDWS indicates that as on 01.04.2019, over 99% of rural HHs in India have toilet access. The declared ODF villages at all India level accounted to 556,824 spreading over 247,723 Gram Panchayats, 6,031 Blocks and 616 Districts[4].

UNICEF in India accords high priority to the provision of safe sanitation and water services to people in rural areas and has over the past many years aided through catalytic technical support to MDWS, Government of India and 15 state governments in the implementation of the various sanitation programmes and since 2014, specifically to the SBM (G). With the progress of the SBM (G), and declaration of ODF communities, there is an emerging question on whether the campaign to eliminate open defecation and create ODF communities is resulting in the decrease in faecal contamination in the environment. This is also an area of interest to UNICEF as it may reveal the impact of the sanitation campaign on environmental faecal contamination, which directly affects children with role in preventing diarrhea, enteric enteropathy, malnutrition and stunting. It would also inform whether corrective measures are

[1]Sustainable Development Goal 6: Ensure availability and sustainable management of water & sanitation for all.
[2]Ministry of Drinking Water and Sanitation; *Swachh Survekshan Gramin* 2016.
[3]Ministry of Drinking Water and Sanitation; Swachh Bharat Mission (Gramin) Division; Issue of Guidelines for ODF verification (Ref No.S-1101113/2015-SBM).
[4] Status of ODF villages as on date, published on the website www.sbm.gov.in

required in India's sanitation mission and also inform UNICEF inputs into the mission. Keeping in view of above, UNICEF partnered with Shriram Institute for Industrial Research (SRI) towards implementation of this scientific study.

1.2 The Scope of Study[5]

The purpose of scientific study is to ascertain contamination levels, related to human and animal *faecal* contamination in Environmental Medium viz. Water, Soil and Food in 4 numbers of villages each in one ODF and one non-ODF district in each of the three states viz. Bihar, Odisha and West Bengal. The overarching aim of study is to assess the effectiveness of sanitation interventions implemented in these villages through various programmes, and to see the effect it has had on the extent of *Faecal* Contamination in the environment of these villages.

It was, therefore, decided to undertake sampling and laboratory investigations as per following scheme:

Testing of 120 number of samples (water, soil and food medium) from villages in one ODF district/ Block and same number, 120 be tested from villages in one non-ODF district/ block in each state. Hence, total number of samples to be sampled and tested in all three states would be 120 x 2 x 3 = 720.

4 ODF villages and 4 non-ODF villages were randomly selected in the identified districts in each state. Samples distribution numbering to 30 in each village, was further categorised as per the following scheme:

(a) Water Samples

Collection of 13 number of samples from each village with following spectrum

(i) Groundwater Source : Public Common Handpumps : 04 samples

(ii) Piped Water Supply : 02 samples (if not available then Public Handpumps)

(iii) Surface Water Samples (Pond, River, Canal etc.) : 03 samples

(iv) Household Sources (such as water storage pot/ vessel/ tank) : 04 samples

Note: In case, sources at (ii), (iii) & (iv) are not adequately available, compensate the same through sampling of additional Public Handpumps.

(b) Soil Samples

Collection of 08 numbers of soil samples as per following distribution:

(i) Near Public Handpumps: 06 samples

(ii) Near Community Toilet: 02 samples

[5]Annexure C: Programme Document_ (2018-19) of Project Cooperation Agreement signed between United Nations Children's Fund (UNICEF) and Implementing Partner (IP) Shriram Institute for Industrial Research on 10 December 2018.

Note: in case of the situation, if community toilet does not exist, the soil samples be taken from the open field having proximity to the current or earlier open defecation spots.

(c) Food Samples

Collection of 09 numbers of cooked food samples as per following proportion:

(i) Hotels/ Dhabas : 05 samples

(ii) School MDM : 02 sample

(iii) Anganwadi MDM : 02 sample

Note: In case, School or *Anganwadi* Centre or both does not exist in village or if available but both or any one of these are not willing to provide sample for testing, then food sampling to be compensated through sampling of additional Dhabi/ hotel food and even if adequate number of dhabas does not exist, compensation to be made through sampling additional public handpump water source.

1.3 Sampling Design

(i) The objective of sampling is to draw a sample small enough in volume to represent the source and be preserved at site prior to transportation to laboratory under the preserved conditions within the maximum permissible time limits. Samples have been drawn in accordance with the guidelines of Standard protocols as mentioned below. The collected samples were transported to laboratory, duly preserved under the specified conditions of maintaining temperature within the maximum permissible time limit.

- IS: 1622-1981 (Reaffirmed 1996); First Revision; 4th Reprint February 2003; Indian Standard; Method of Sampling and Microbiological Examination of Water.
- APHA, AWWA.WEF; 23rd Edition 2017; Standard Method for Examination of Water and Wastewater.
- IS: 3025 (Pt-1) Reaffirmed 2014.

(ii) The samples were collected in bottles sterilised through Gamma-irradiation.

(iii) Sampling formats included site identification information such as State/ District/ GP/ Village/ Habitation; Nearest Caretaker/ Household/ Landmark; GPS Geocodes and General Site/ Vicinity Observations.

Following formats were used during sampling and survey

- UNICEF/SRI/PCA/PD 2018-19/ODF Study/01
- UNICEF/SRI/PCA/PD 2018-19/ODF Study/02
- UNICEF/SRI/PCA/PD 2018-19/ODF Study/03
- UNICEF/SRI/PCA/PD 2018-19/ODF Study/04

Following information collected/ generated at site:

(a) Obtained signatures, name and contact details of the member/s (whosoever available) of the Village, like *Pradhan*, *Panchayat* member, School teacher, *Anganwadi* worker, Auxiliary Nurse Midwife (ANM) worker; Accredited Social Health Activist (ASHA) etc., verifying the location, collection of samples and date.

(b) Taken GPS coordinates of each sample collection site.

(c) Taken photographs of the sample collection from each site.

1.4 Selection of District and Villages

(a) Selection of District

Selection of the ODF District and non-ODF district: decided and provided by the state Government and UNICEF, considering:

- The status of the districts in the state : ODF and non-ODF
- The proximity of the District to the nearest airport to allow for easy transportation of sample to the laboratory

(b) Selection of Villages

(i) ODF: From amongst the ODF villages in the ODF district/Block, villages with the following 2 conditions were shortlisted, and 10 randomly selected in the list
  - Population of the village to be > 500 persons (2011 census)
  - Village should be ODF for at least 6 months

(ii) Non-ODF: From amongst the non- ODF villages in the non- ODF district/Block, 10 villages with the following 2 conditions were shortlisted, and 10 randomly selected in the list
  - Population of the village to be > 500 persons (2011 census)
  - Village toilet coverage be in the bottom quartile of the district

(iii) Out of the shortlisted villages in each category, 4 ODF and 4 non-ODF villages per district were further randomly selected by UNICEF using random number generation method random.org.

2. Testing Methodology

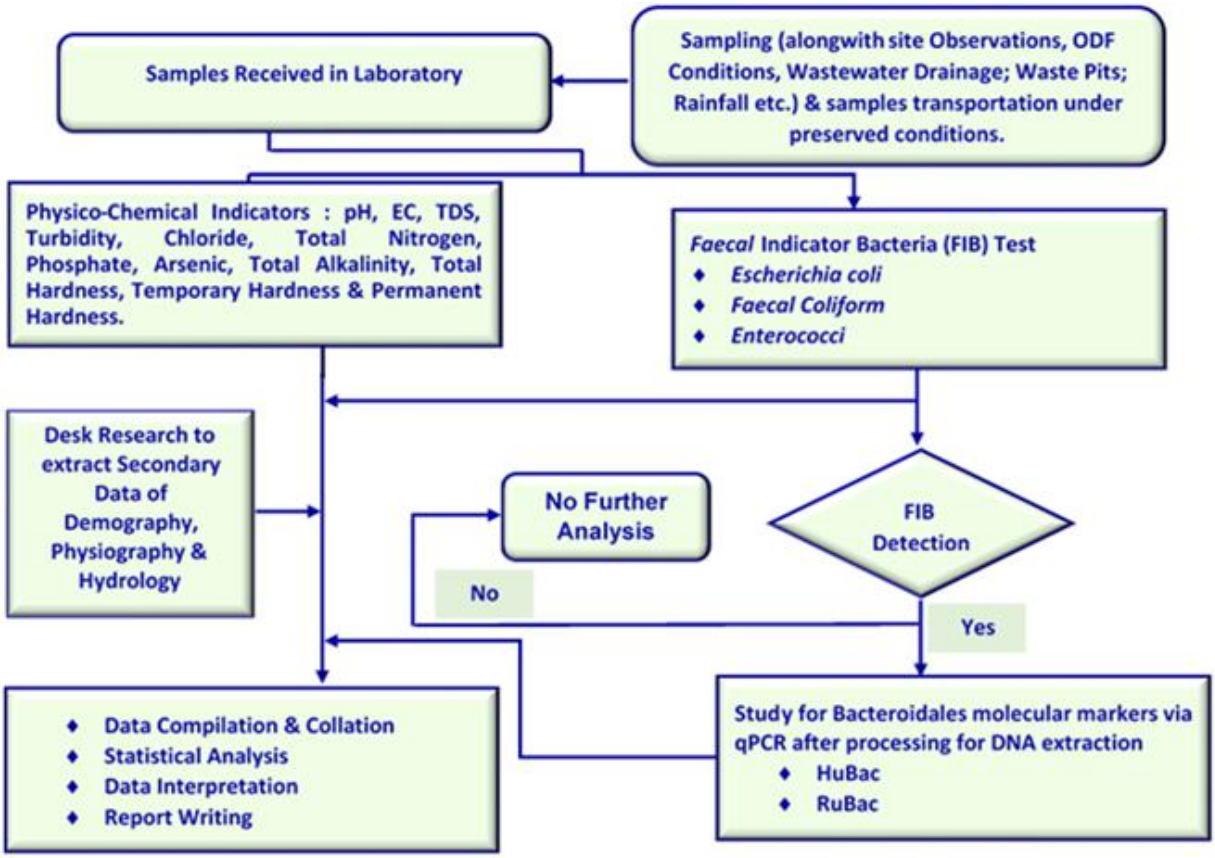
2.1 Sample Analysis, Data Collection (Secondary & During Sampling/ Survey)

(i) All the preserved samples shall be analysed for specified parameters in accordance with the guidelines of the relevant protocols (BIS: Relevant Specifications; APHA 23rd Edition).

(ii) In order to assess microbial contamination of water, food & soil samples collected from ODF and non-ODF locations, Microbial Source Tracking (MST) studies shall be conducted to unravel microbial contamination, if found positive, due to *Human or Animal or both* Origin.

(iii) The overall process to be followed would be as follows:

Figure-1 : Process flow chart of methodology



(iv) Following physico-chemical parameters are to be analysed

- pH
- Turbidity
- EC
- TDS
- Chloride
- Total Kjeldahl Nitrogen
- Phosphorous
- Total Hardness
- Total Alkalinity
- Arsenic

2.2 Significance of Test Parameters

The significance of test parameter selected for study is described below:

Table-1 Significance of Test Parameters

Test Parameters	**Significance**
Microbiological Parameters and Bacteroidales molecular markers	
Fecal coliforms	*Faecal* Indicators Bacteria (FIB) Group; These parameters are useful for screening the media, if it is contaminated with Microorganisms of *Faecal* Origin.
Escherichia coli	
Enterococci	
Bacteroidales molecular markers ♦ HuBac ♦ RuBac	Microbial Source Trackers (MST); the bacteroidales molecular markers helps in identifying the source of faecal origin.
Water physic-chemical parameters	
pH	Indicates acidic/ alkaline/ normal character of water
Turbidity	Rapid method for screening contamination based on visual quality.
EC/TDS and Chloride	*Faecal* matter is one of the source of Chloride
Nitrogen and Phosphorous	*Faecal* matter is the significant source
♦ Hardness (Total, Temporary & Permanent) ♦ Alkalinity	Influence Water Stoichiometry and Contamination
Arsenic	Toxic Metal; Its presence may inhibit the growth of bacteria

2.3 Protocols/ Methods of Test

The protocols/ Method of Tests are described in following table:

Table-2 Protocols/ Methods of Test

Test Parameters		**Protocol/ Method of Test**	
Fecal coliforms		IS:1622:1981(amended to date); MF Technique	
Escherichia coli		IS:9308-2014 part-1 (amended to date)	
Enterococci		IS : 15186/ ISO 7899 part-2 (amended to date)	
Bacteroidales molecular markers ♦ HuBac ♦ RuBac		Sample positive with FIB to be processed for DNA extraction and to be analysed via Quantitative real-time polymerase chain reaction (qPCR) for Bacteroidales molecular markers.	
Physico-Chemical Test in Water	pH	IS : 3025 (Pt-11) Reaffirmed 2017	Standard Methods for Examination of Water and Wastewater; APHA; AWWA; WEF; Ed.23rd 2017
	EC	IS : 3025 (Pt-14) Reaffirmed 2013	
	TDS	IS : 3025 (Pt-16) Reaffirmed 2017	
	Turbidity	IS : 3025 (Pt-10) Reaffirmed 2017	
	Chloride	IS : 3025 (Pt-32) Reaffirmed 2014	
	Total Kjeldahl Nitrogen	IS : 3025 (Pt-34) Reaffirmed 2014	
	Phosphorous	IS : 3025 (Pt-31) Reaffirmed 2014	
	Hardness	IS : 3025 (Pt-21) Reaffirmed 2014	
	Total Alkalinity	IS : 3025 (Pt-23) Reaffirmed 2014	

2.4 Risk Calculation[6]

Relative risk has been calculated by following method:

Table-3 Risk Calculation Matrix

Interventions	**Contamination of Environment Medium (e.g Water, Soil & Food)**		**Total**
	Yes	**No**	
Villages with non-ODF	A	B	(A+B)
ODF villages	C	D	(C+D)
Total	(A+C)	(B+D)	(A+B+C+D)
Probability of Contamination in non-ODF villages = A/(A+B) = E **Probability of contamination in ODF villages = C/(C+D) = F** **Relative Risk = E/F**			

[6] Chittranjan Andrade; Understanding Relative Risk, Odds Ratio and Related Terms; J Clin Psychiatry 76:7, July 2015.

3. Study Outcome : Odisha

3.1 Description of Villages Selected for Study in Odisha

The profile of villages selected from ODF and non-ODF blocks of Odisha, is illustrated below:

Table-4 Profile of villages in ODF blocks of Odisha

State	**Odisha: ODF**			
District	**Jagatsinghpur**		**Puri**	
Block	**Biridi**		**Delanga**	
Village	Kulakaijanga	Purana	Indipurdeuli	Ramachandrapur
Total Population	2241	2146	3604	956
Is Declared ODF	Yes	Yes	Yes	Yes
Is Verified ODF	Yes	Yes	Yes	Yes
Total HH	686	830	926	174
HH with Toilets	686	830	926	174
HH accessing CAOT	0	0	0	0
Remaining HH	0	0	0	0
% coverage	100	100	100	100
ODF Declared date	17/04/18	21/04/18	19/10/17	22/05/18

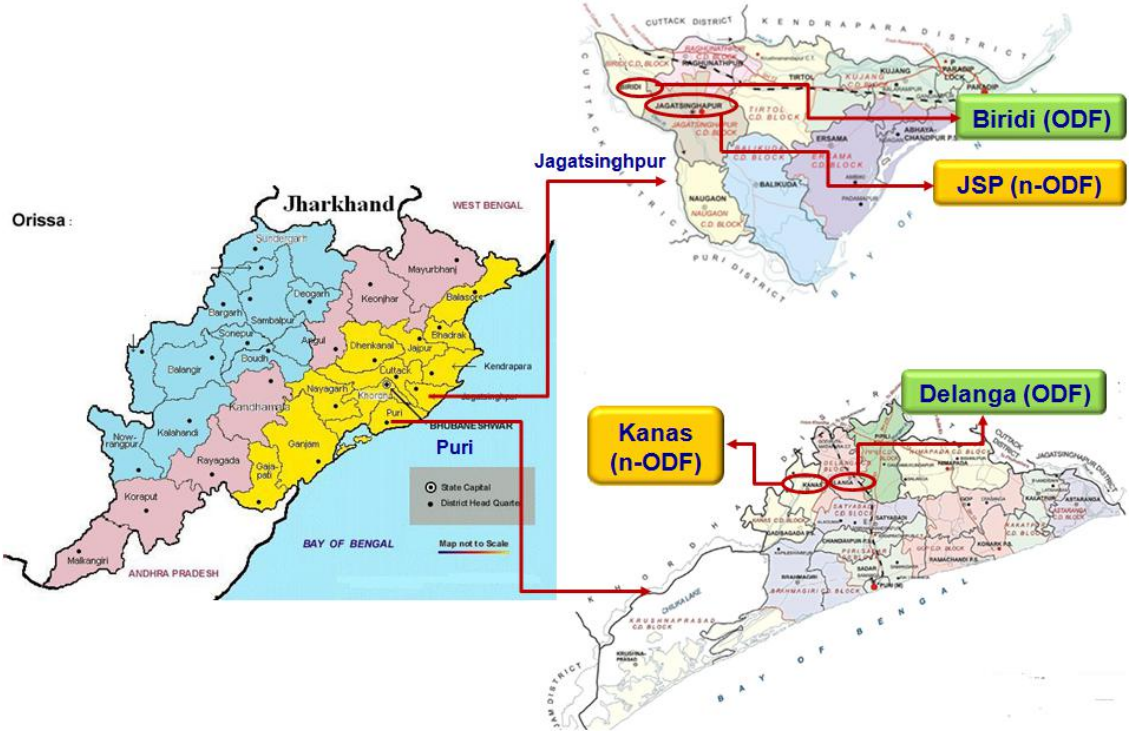
CAOT: Community and Other Toilets

Table-5 Profile of villages in non-ODF blocks of Odisha

State	**Odisha : non-ODF**			
District	**Jagatsinghpur**		**Puri**	
Block	**Jagatsinghpur**		**Kanas**	
Village	Rasalpur	Ningaon	Dupur	Balipatna
Total Population	2498	860	587	1179
Is Declared ODF	No	No	No	No
Is Verified ODF	No	No	No	No
Total HH	807	210	96	186
HH with Toilets	495	134	4	16
HH accessing CAOT	0	0	0	0
Remaining HH	312	76	92	170
% coverage	61.34	63.81	4.17	8.6
ODF Declared date	-	-	-	-

CAOT: Community and Other Toilets

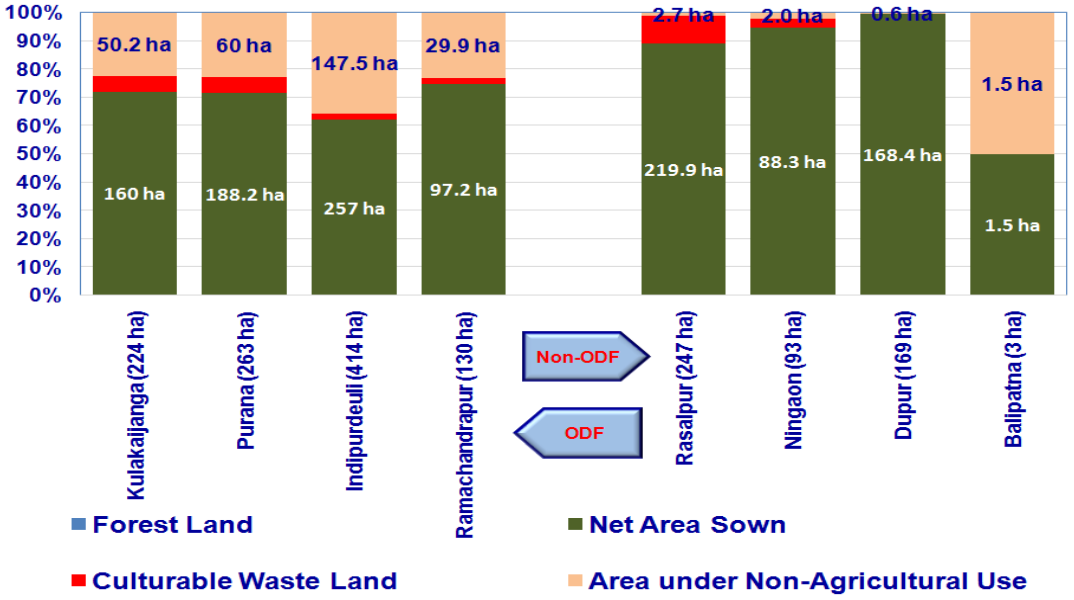
Figure-2 Study Areas in Odisha



3.2 Landuse of ODF and non-ODF villages in study area of Odisha

62.1% to 74.8% area in ODF villages and 50.0 to 99.6% area in non-ODF villages is under Agricultural Use (Net Sown Area), whereas 2.2 to 5.7% area in ODF villages and 0 to 9.9% area in non-ODF villages is Culturable Waste Land.

Figure-3 Landuse in Study Areas (ODF and Non-ODF villages) of Odisha



3.3 Summary of Sample Collection from Odisha

Summary of samples collection from Odisha is described in following table.

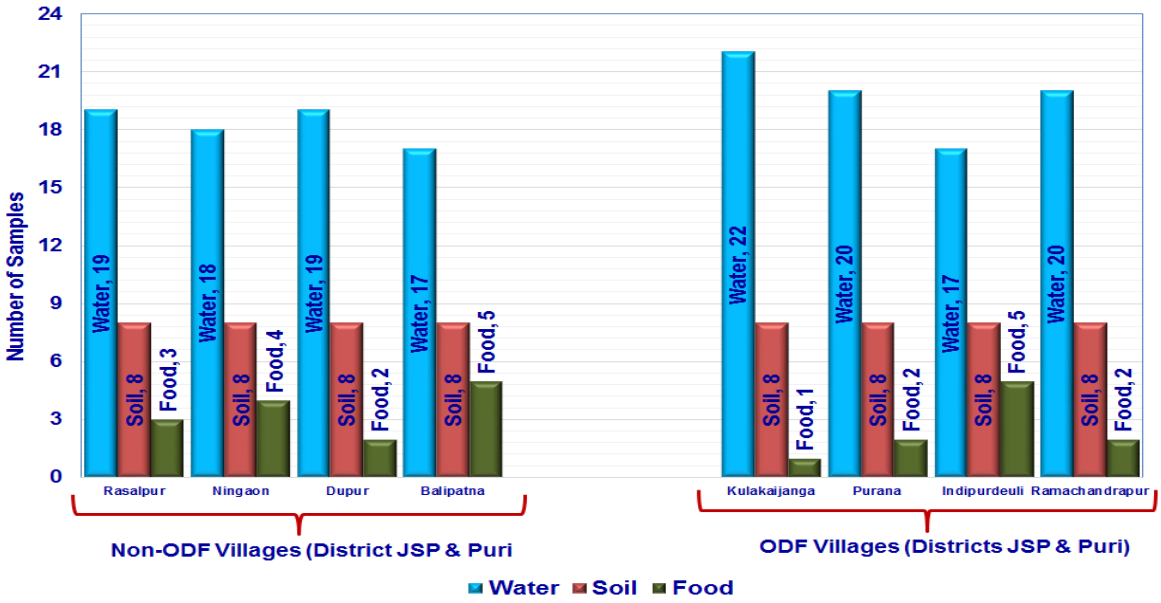
Table-6 Summary of Samples Collection from Odisha

District	Block	GP	Village	DOS	Environmental Medium			
					Water	Soil	Food	Total
Jagatsinghpur	Biridi (ODF)	Purana	Purana	18.12.18	20	08	02	30
		Kulakaijanga	Kulakaijanga	18.12.18	02	02	01	31
				20.12.18	20	06	00	
	JSP (N-ODF)	Jasobasantapur	Rasalpur	18.12.18	13	06	03	30
				20.12.18	06	02	00	
		Jahanpur	Ningaon	18.12.18	18	08	04	30
Puri	Delanga (ODF)	Delangkothabada	Ramachandrapur	19.12.18	20	08	02	30
		Abhayamukhi	Indipurdeuli	19.12.18	17	08	05	30
	Puri (N-ODF)	Alibada	Dupur	19.12.18	19	08	02	29
		Badas	Balipatna	19.12.18	17	08	05	30
Total					**152**	**64**	**24**	**240**

Remarks

- Food was not available in eating shops in any of the village.
- Midday Meals (MDM) available in *Anganwadi* & Schools were collected, wherever it was available.
- In Puri district, MDM is prepared by the contractor at block level, is being distributed to all schools. Hence, food samples at distribution end were collected from available schools in the village.

Figure-4 Village wise spectrum of samples collected in Odisha



240 numbers of sample (121 numbers form ODF and 119 numbers from non-ODF villages) were collected.

3.4 Rainfall Conditions at Site

Sampling work undertaken from 18-20/12/2018; Heavy rain occurred on the night of 17/12/2018 and early morning of 18/12/2018. No rainfall notices during the remaining sampling period.

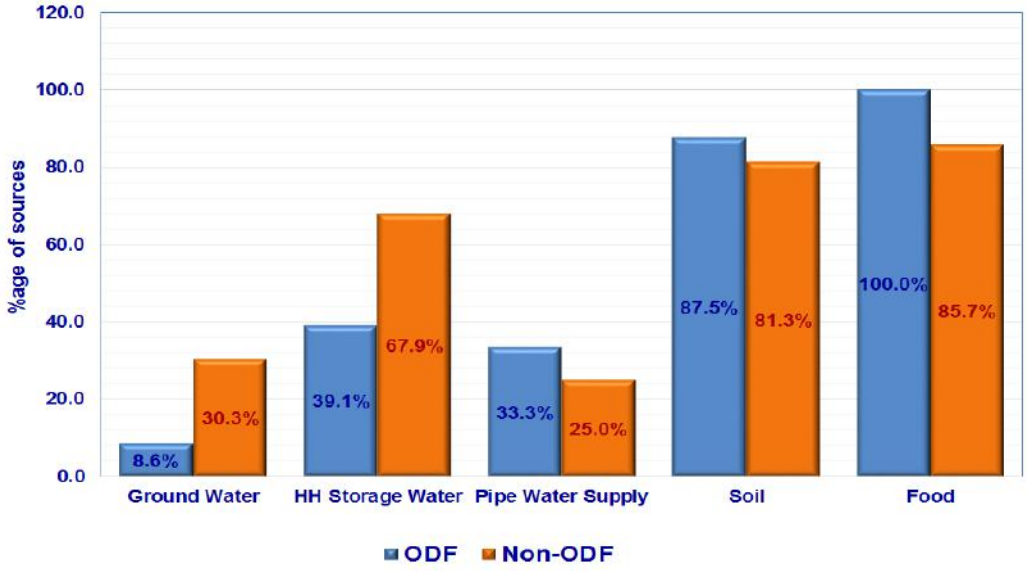
3.5 Summary of Study Outcome: Odisha

Study findings with respect to (i) Faecal Indicator Bacteria [Faecal coliform, Organisms (MPN/100 ml in case of water and MPN/g in case of soil and food), Escherichia coli (cfu/100 ml in case of water and cfu/g in case of soil and food) and Enterococci (cfu/100 ml in case of water and cfu/g in case of soil and food)]; (ii) Bacteroidales molecular markers (a) HuBac and (b) RuBac and (iii) Physico-chemical properties of water in Odisha, are presented in table-6 and 7. Detailed study results are given in the Annexure. The study can be summed up as follows.

(A) Risk of Faecal Contamination of ODF and non-ODF villages

(a) In ODF villages, 38 numbers of ground water samples were analysed, whereas in non-ODF villages 33 numbers of ground water samples were analysed. In ODF villages 8.6% sources were found contaminated, whereas in non-ODF villages, 30.3% sources were found contaminated.

Figure-5 %age of sources contaminated with FIB



(b) 12 numbers of surface water sources were analysed in ODF villages, whereas in non-ODF villages, number of surface water samples analysed were 08. In both ODF and non-ODF villages, 100% sources were found contaminated with FIB.

(c) 23 numbers of household water storage samples were analysed in ODF villages, whereas in non-ODF villages, number of corresponding number of samples analysed were 28. In ODF villages 39.1% sources were found contaminated, whereas in non-ODF villages, 67.9% sources were found contaminated.

(d) 06 numbers of piped water supply samples were analysed in ODF villages, whereas in non-ODF villages 04 number of samples were analysed. In ODF villages 33.3% sources were found contaminated, whereas in non-ODF villages, 25.0% sources were found contaminated.

(e) In case of soil, 32 number of samples were analysed both in ODF and non-ODF villages. In ODF villages 87.5% sources were found contaminated, whereas in non-ODF villages, 81.3% sources were found contaminated.

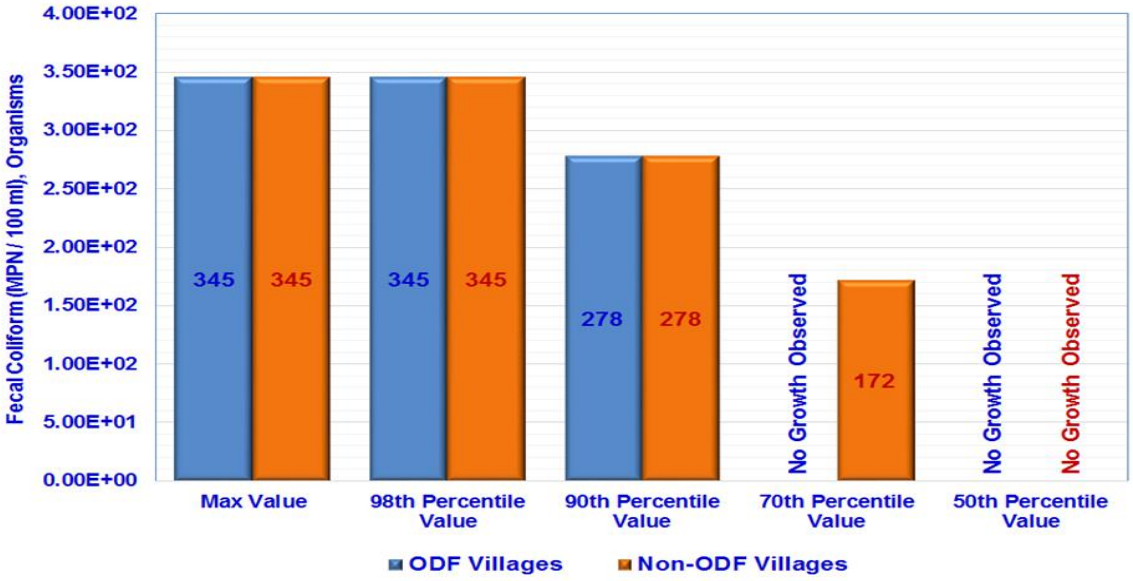
(f) In case of food (MDM only from School and Anganwadi), 10 number of samples were analysed in ODF and 14 numbers in non-ODF villages. 100% samples were found contaminated in ODF villages and 85.4% in non-ODF villages.

The risk of faecal contamination in non-ODF villages in comparison to ODF villages was found to be, 3.54 times more likely in case of groundwater; equal in case of surface water; 1.73 times more likely in case household storage water; 0.75 times more likely in case piped water supply; 0.93 times more likely in case of soil; and 0.90 times more likely in case of food.

(B) Faecal Indicator Bacteria in Water

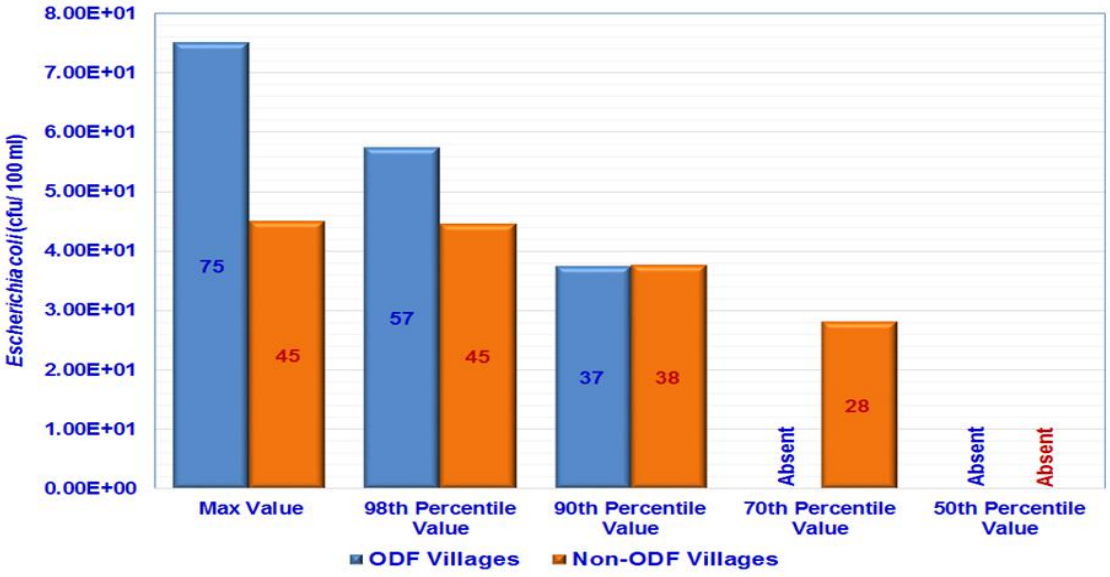
(a) Maximum and 98th percentile values of faecal coliform, in water both from ODF and non-ODF villages, are observed 345 Organisms (MPN coliform/ 100 ml). The 70th percentile onward values of faecal coliform in water samples of ODF villages showed "No Growth".

Figure-6 Faecal coliform, Organisms (MPN coliform/ 100 ml) in water



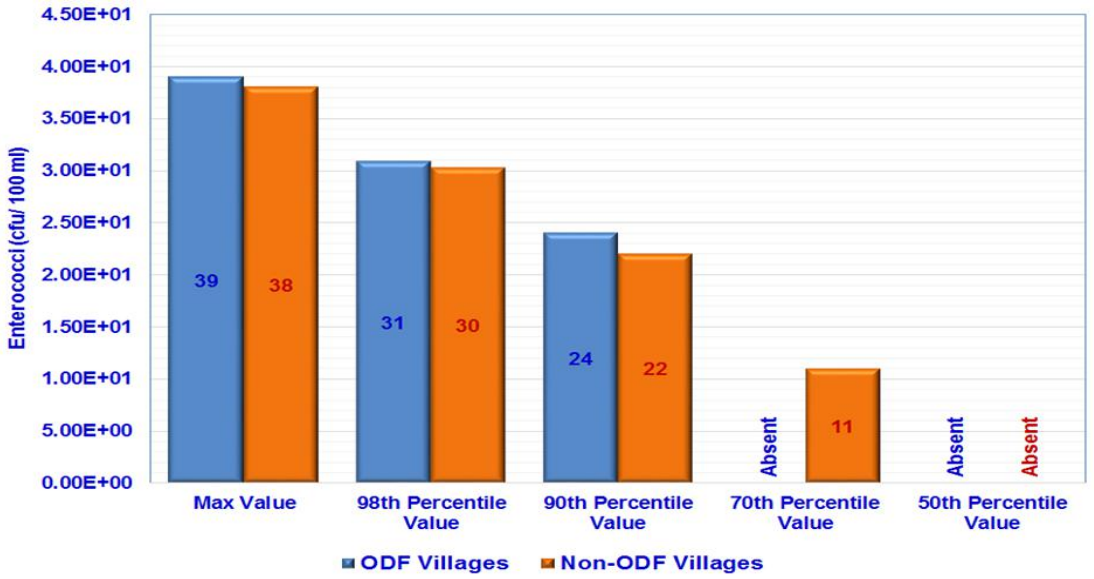
(b) Maximum values of *Escherichia coli*, in water of ODF and non-ODF villages, are observed 75 cfu/ 100 ml and 45 cfu/ 100 ml respectively. The 70th percentile onward values of *Escherichia coli* in water samples of ODF villages are found "Absent".

Figure-7 *Escherichia coli* (cfu/ 100 ml) in water



(c) Maximum values of *Enterococci*, in water of ODF and non-ODF villages, are observed 39 cfu/ 100 ml and 38 cfu/ 100 ml. The 70th percentile onward values of *Enterococci* in water samples of ODF villages are found "Absent".

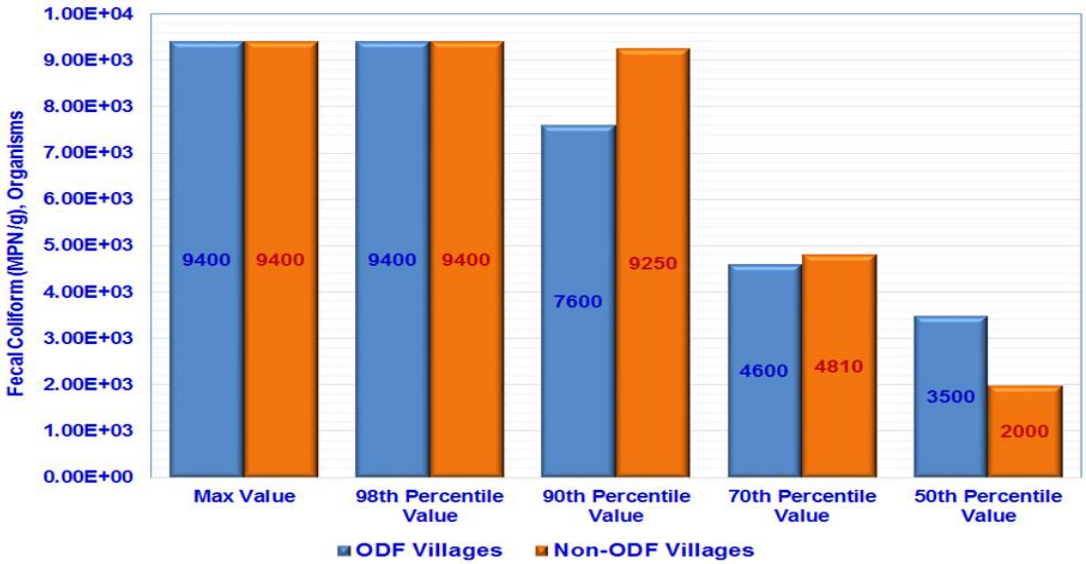
Figure-8 Enterococci (cfu/ 100 ml) in water



(C) Faecal Indicator Bacteria in Soil

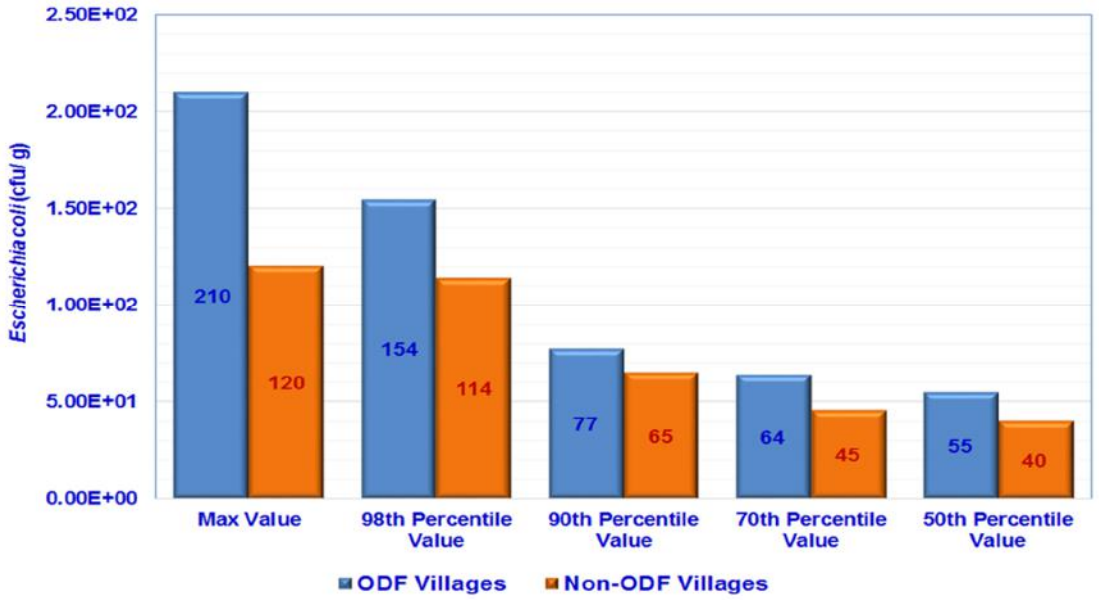
(a) Maximum and 98th percentile values of faecal coliform, in soil samples taken both from ODF and non-ODF villages, are observed 9400 Organisms (MPN coliform/g). The 50th percentile values in ODF and non-ODF villages, are observed 3500 MPN coliform/g and 2000 MPN coliform/g respectively.

Figure-9 Faecal coliform, Organisms (MPN coliform/ g) in soil



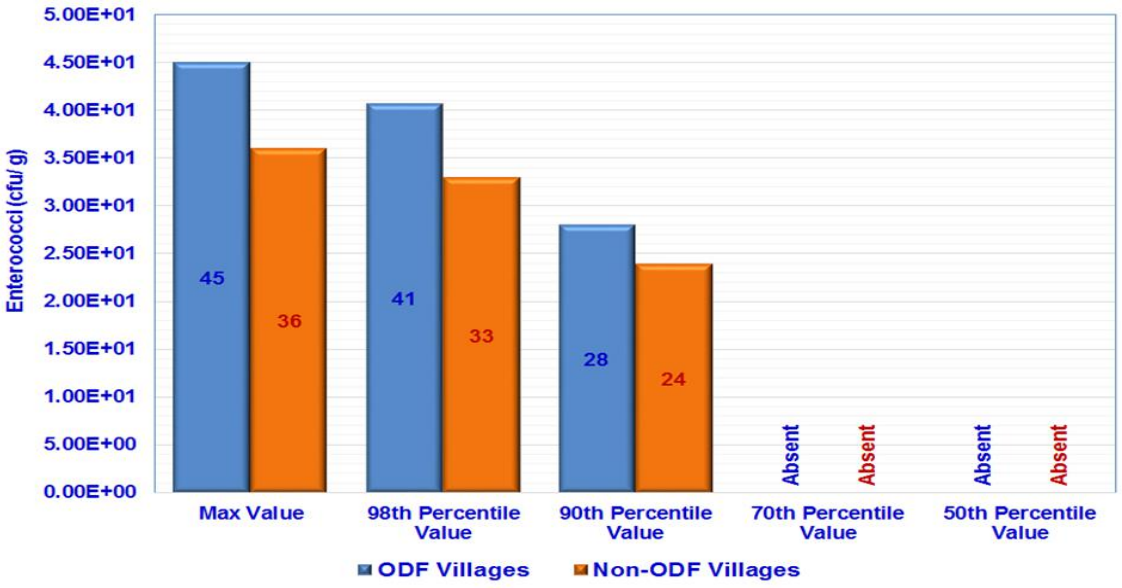
(b) Maximum values of *Escherichia coli*, in soil samples collected from ODF and non-ODF villages, are observed 210 cfu/g and 120 cfu/g respectively. The 50th percentile values in ODF and non-ODF villages, are observed 55 cfu/ g and 40 cfu/ g respectively.

Figure-10 *Escherichia coli* (cfu/ g) in soil



(c) Maximum values of *Enterococci*, in soil samples collected from ODF and non-ODF villages, are observed 45 cfu/g and 36 cfu/g respectively. The 70th percentile onward values both in ODF and non-ODF villages, are observed "Absent".

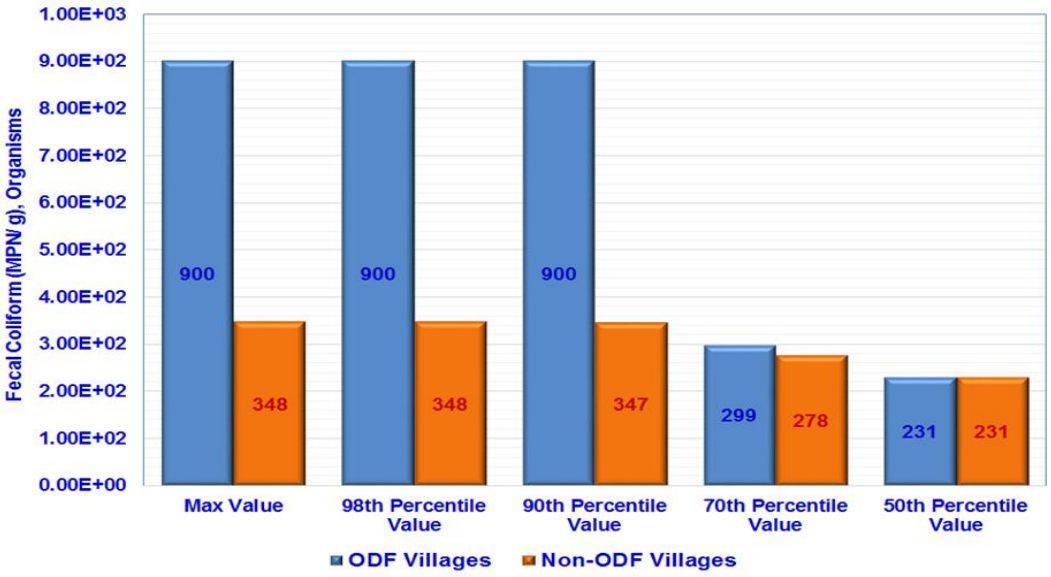
Figure-11 *Enterococci* (cfu/ g) in soil



(D) Faecal Indicator Bacteria in Food

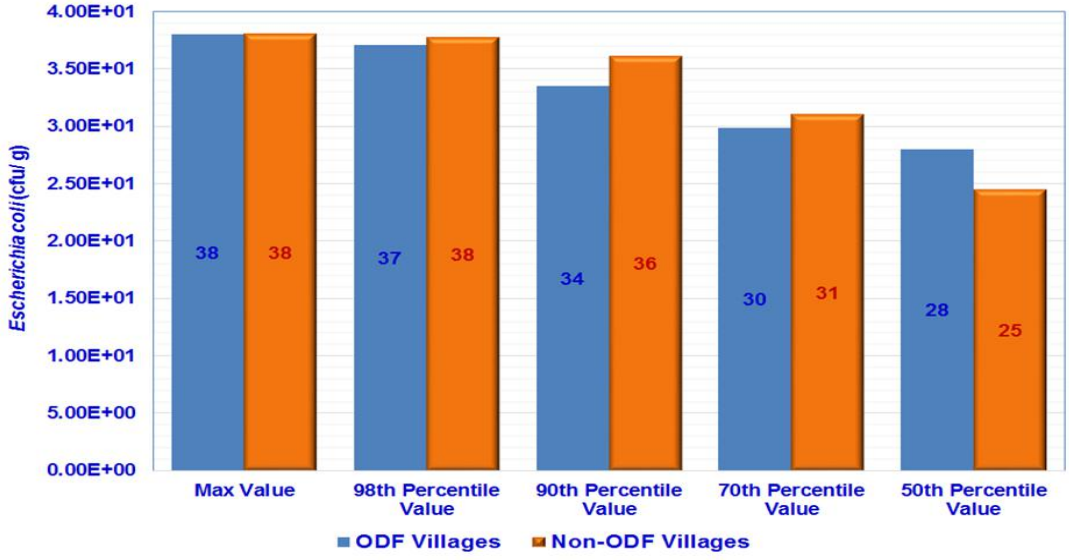
(a) Maximum and 98th percentile values of faecal coliform, in food samples taken both from ODF and non-ODF villages, are observed 900 and 348 Organisms (MPN coliform/g) respectively. The 50th percentile value both in ODF and non-ODF villages, is observed 231 MPN coliform/g.

Figure-12 Faecal coliform, Organisms (MPN coliform/ g) in food



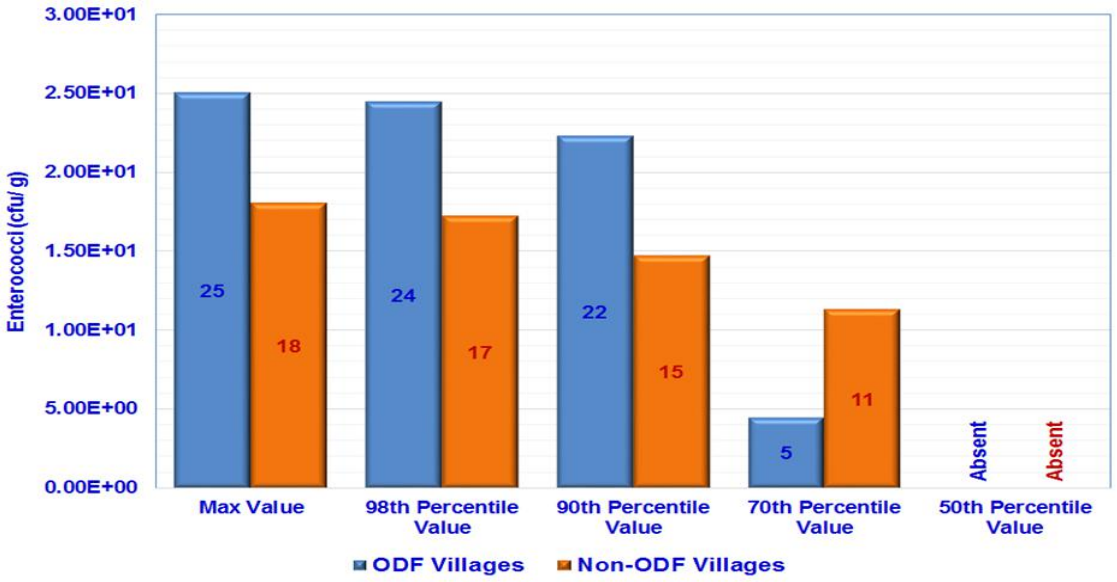
(b) Maximum values of *Escherichia coli*, in food samples taken both from ODF and non-ODF villages, is observed 38 cfu/g. The 50th percentile values in ODF and non-ODF villages, are observed 28 and 25 cfu/g respectively.

Figure-13 *Escherichia coli* (cfu/ g) in food



(c) Maximum values of *Enterococci*, in food samples collected from ODF and non-ODF villages, are observed 25 cfu/g and 18 cfu/g respectively. The 50th percentile onward values both in ODF and non-ODF villages, are observed "Absent".

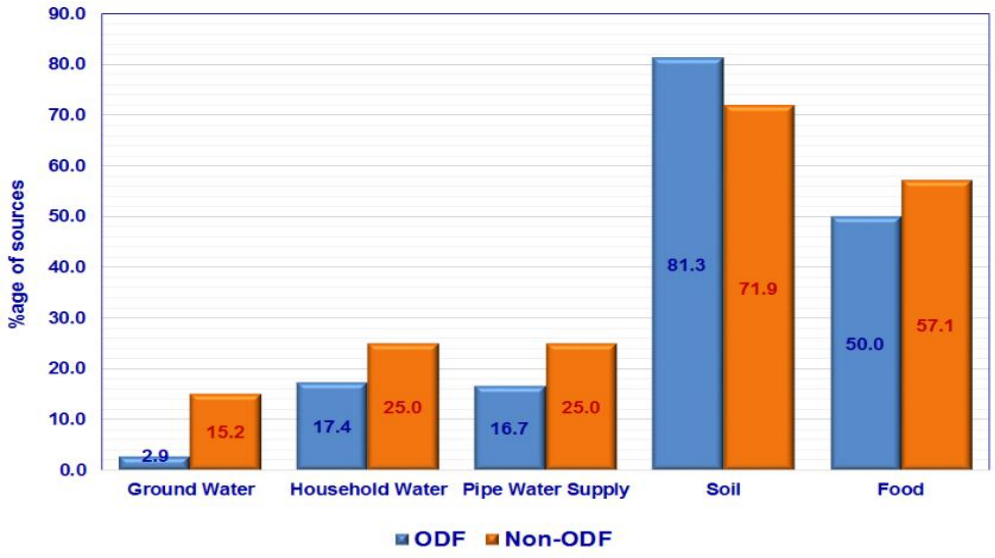
Figure-14 *Enterococci* (cfu/ g) in food



(E) Risk of ODF and non-ODF villages due to Faecal Contamination of Human Origin

The risk of faecal contamination due to human origin (HuBac) in non-ODF villages in comparison to ODF villages was, 5.3 times more likely in case of groundwater; equal in case of surface water; 1.44 times more likely in case of household water; 1.50 times more likely in case of piped water supply; 0.89 times more likely in case of soil; and 1.14 times more likely in case of food.

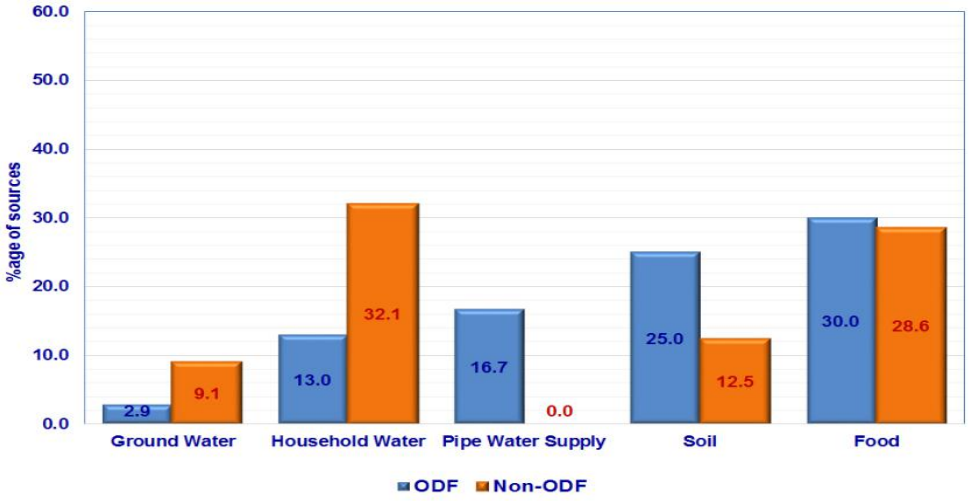
Figure-15 Faecal contamination due to Human Origin



(F) Risk of ODF and non-ODF villages due to Faecal Contamination of Animal Origin

The risk of faecal contamination due to animal origin (RuBac) in non-ODF villages in comparison to ODF villages was found to be, 3.18 times more likely in case of ground water; 1.31 times more likely in case of surface water; 2.46 times more likely in case of household storage water; 0.75 times more likely in case of piped water supply; 0.5 times more likely in case of soil; and 0.95 times more likely in case of food.

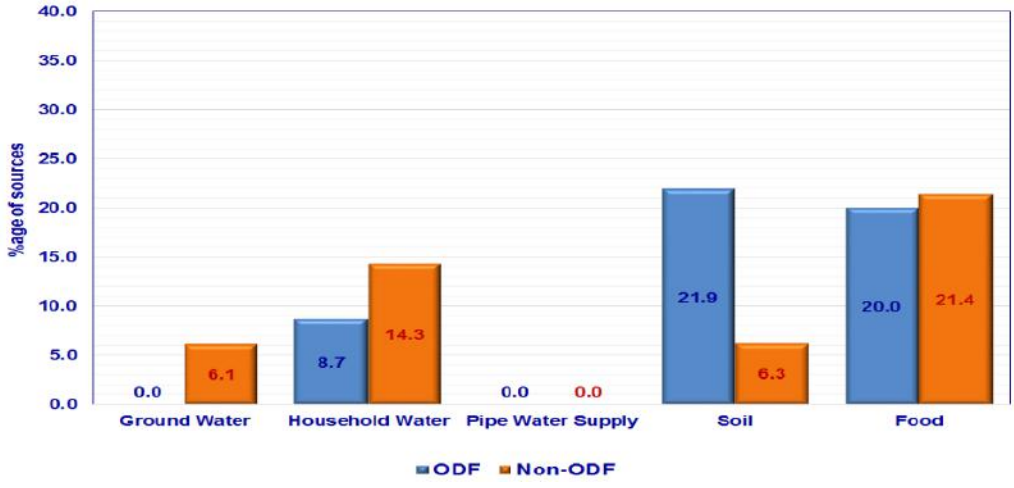
Figure-16 Faecal contamination due to Animal Origin



(G) Risk of ODF and non-ODF villages due to Faecal Contamination of both Human and Animal Origin

The risk of faecal contamination both due to human origin (HuBac) and animal origin (RuBac) in non-ODF villages in comparison to ODF villages was found to be, 4.24 times more likely in case of ground water; 1.50 times more likely in case of surface water; 1.64 times more likely in case of household water storage; 1.50 times more likely in case of piped water supply; 0.28 times more likely in case of soil; and 1.01 times more likely in case of food.

Figure-17 Faecal contamination both due to Human and Animal Origin



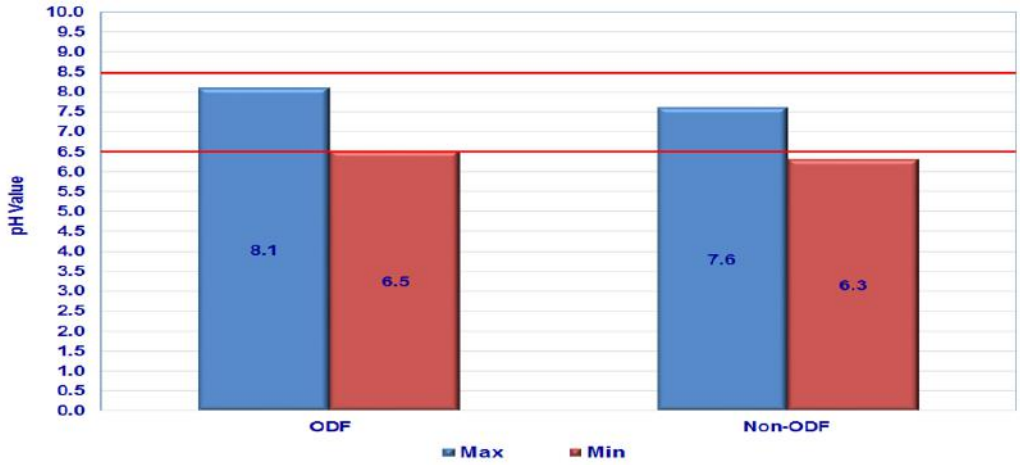
(H) Physico-chemical Properties of Water Sources in ODF and non-ODF villages

(Acceptable and maximum permissible, wherever available, are shown by red lines on the graph)

(a) pH value of water

pH value is ranging between 6.5 to 8.5 in ODF and 6.3 to 7.6 in non-ODF, which indicates normal pH level except at one source in non-ODF village.

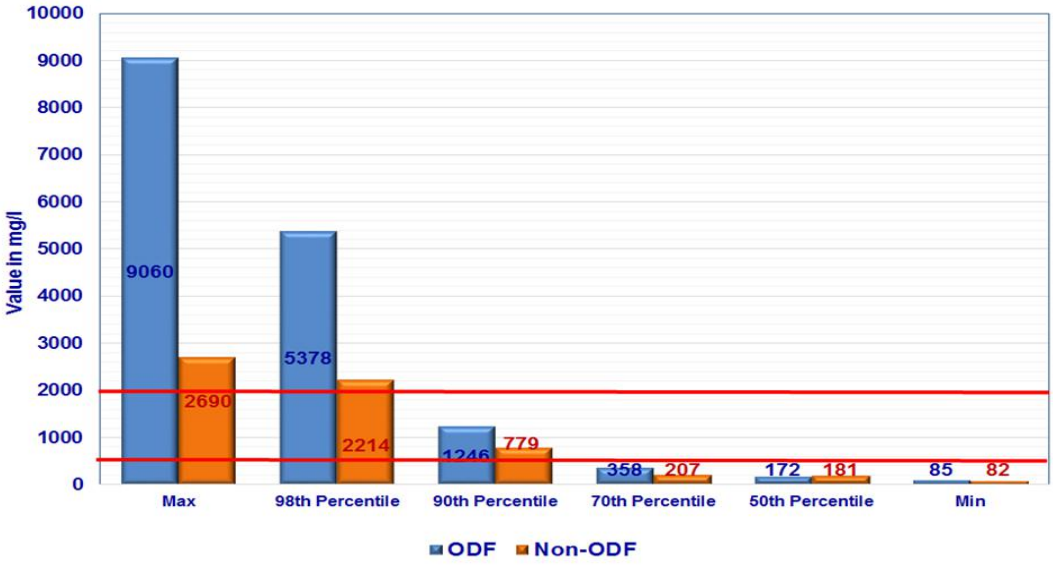
Figure-18 pH value of Water



(b) Total Dissolved Solids (TDS) in water

TDS is found ranging between 85 to 9060 mg/l (exceeding normal values in Indipurdeuli village) in ODF villages and 82 to 2690 mg/l (exceeding normal values in Balipatna village) in non-ODF villages. 90th percentile onward values of TDS are well within the normal values.

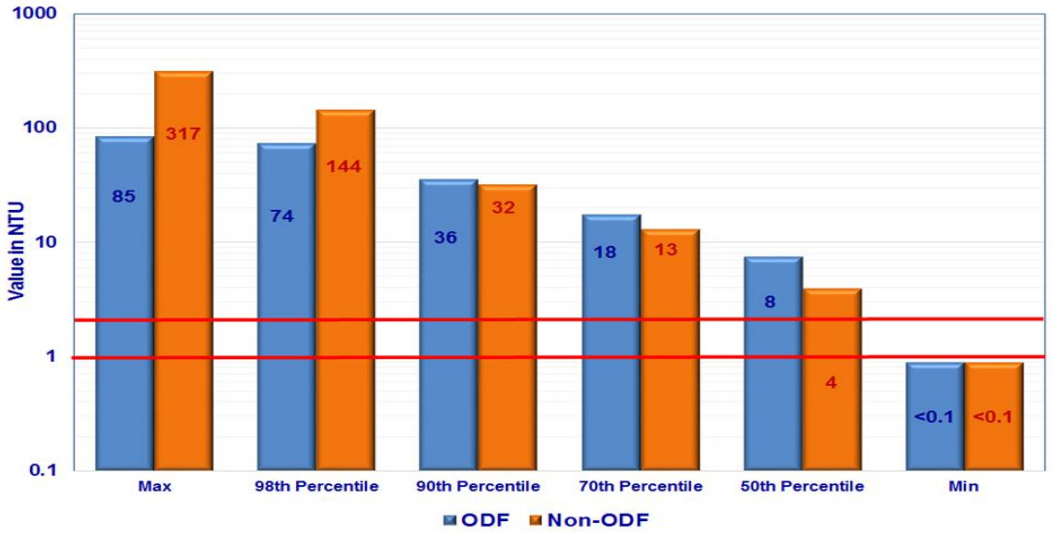
Figure-19 Total Dissolved Solids (TDS) in Water



(c) Turbidity in water

Turbidity in most of the samples of water both in ODF and non-ODF villages is found exceeding the norms.

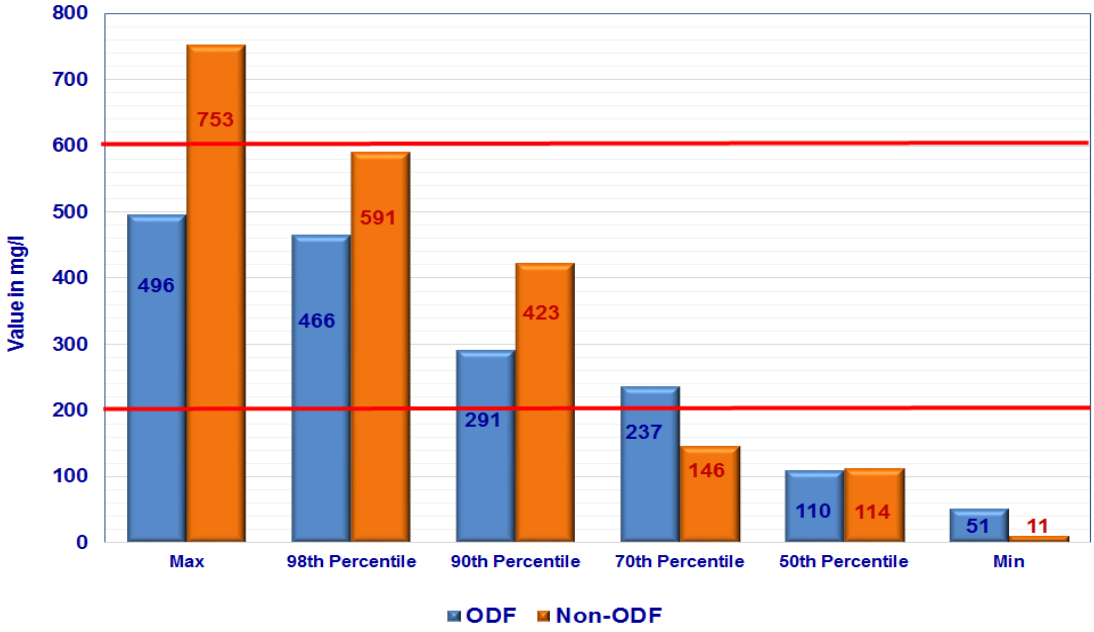
Figure-20 Turbidity in Water



(d) Total Alkalinity in water

Total Alkalinity as $CaCO_3$ is found ranging between 51 to 496 mg/l in ODF villages and 11 to 753 mg/l in non-ODF villages. The 98th percentile onward values of total alkalinity are found well within the norms of drinking water.

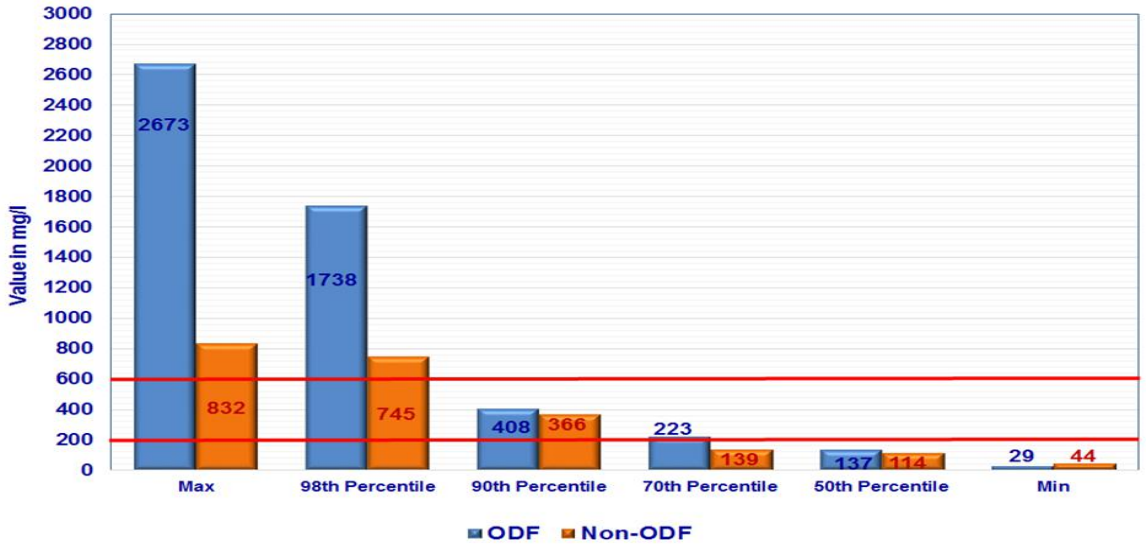
Figure-21 Total Alkalinity in Water



(e) Total Hardness in water

Total Hardness as $CaCO_3$ is found ranging between 29 to 2673 mg/l in ODF villages and 44 to 832 mg/l in non-ODF villages. The 90th percentile onward values of total alkalinity are found well within the norms of drinking water.

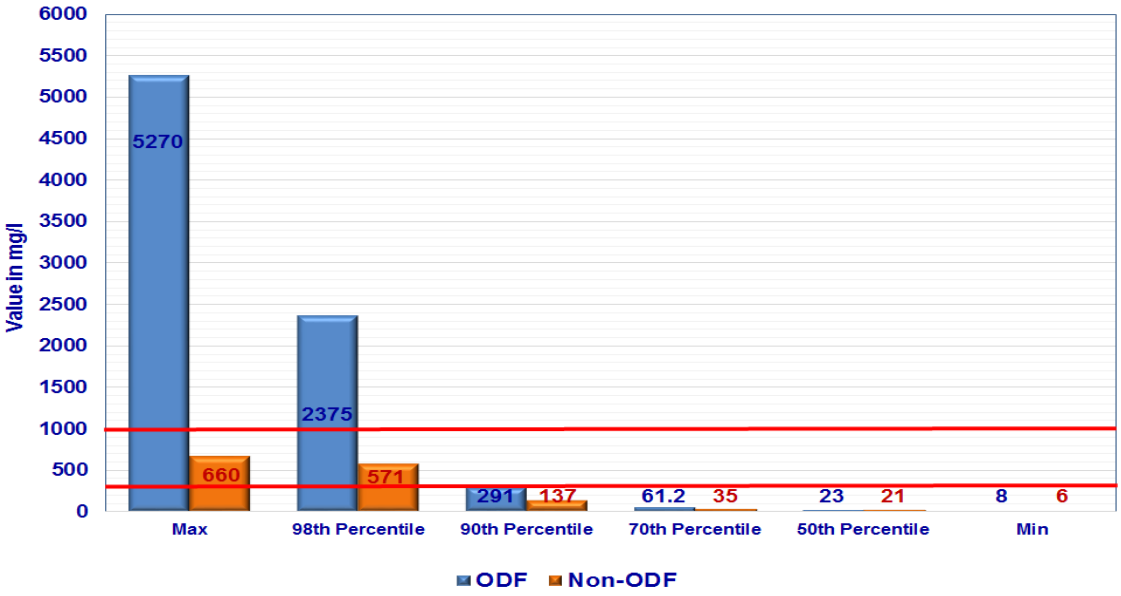
Figure-22 Total Hardness in Water



(f) Chlorides in water

Chloride as Cl is found ranging between 8 to 5270 mg/l in ODF villages and 8 to 660 mg/l in non-ODF villages. The 90th percentile onward values of chlorides are found well within the norms of drinking water.

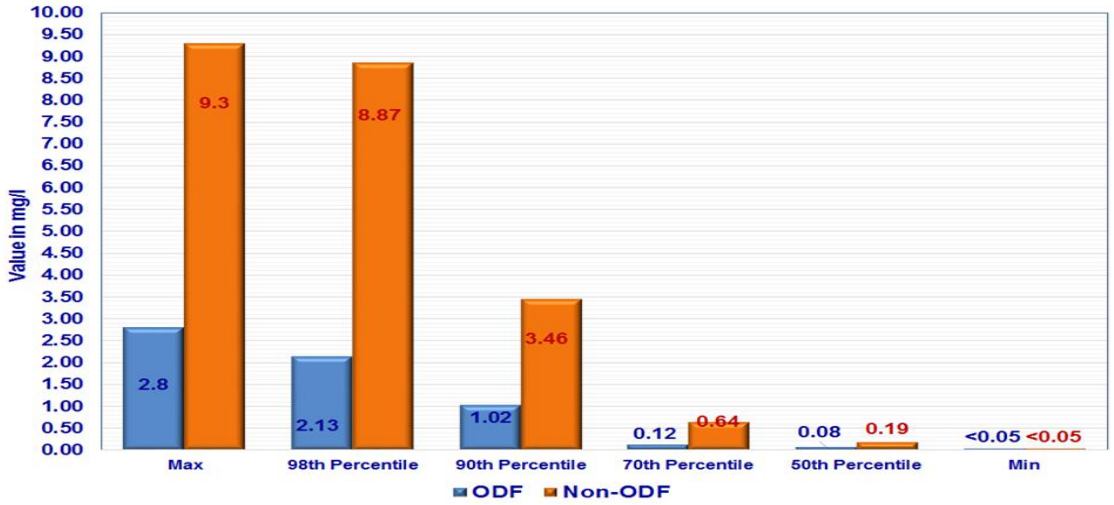
Figure-23 Chlorides in Water



(g) Total phosphorous in water

Phosphorous as P is estimated <0.05 to 2.8 mg/l in ODF villages and <0.05 to 2.9 mg/l in non-ODF villages. The 70th percentile onward values of phosphorous are found below 1.0 mg/l.

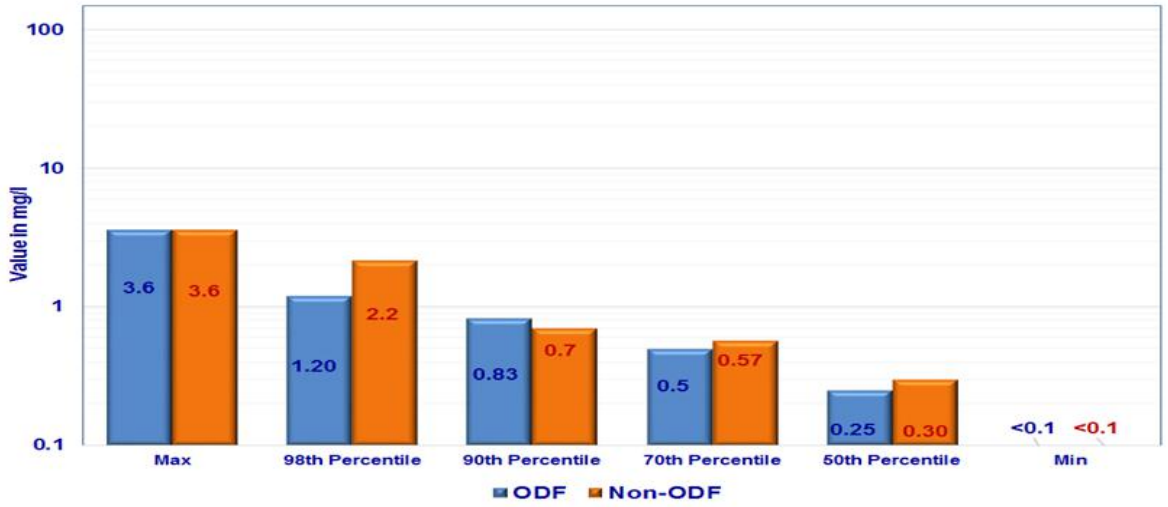
Figure-24 Total phosphorous in water



(h) Total Kjeldahl Nitrogen in water

Total Nitrogen as N is found ranging between <0.1 to 3.6 mg/l in ODF villages and <0.1 to 3.6 mg/l in non-ODF villages. The 90th percentile onward values of nitrogen are found below 1.0 mg/l.

Figure-25 Total Nitrogen in water



(i) Arsenic in water

Except at two locations in Indipurdeuli villages (ODF) where Arsenic is found 0.027 and 0.026 mg/l slightly above the normal value (0.01 mg/l), at all other locations both in ODF and non-ODF, it is Not Detected (Detection Limit 0.01 mg/l).

Table-7 Summary of Findings: ODF Villages in Odisha

District			**Jagatsinghpur (ODF)**		**Puri (ODF)**	
Block			**Biridi**		**Delanga**	
Village			Kulakaijanga	Purana	Indipurdeuli	Ramachandrapur
Is Declared ODF			Yes	Yes	Yes	Yes
HH with toilets (% coverage)			100	100	100	100
Environmental Medium			**%age of sampled sources found contaminated**			
Water	Ground Water	FIB	0 %	0%	28.6%	10.00
		RuBac	-	-	14.3%	0%
		HuBac	-	-	14.3%	0%
	Surface Water	FIB	100%	100%	100%	100%
		RuBac	100%	25.0%	66.7%	100%
		HuBac	66.7%	50.0%	0%	100%
	HH Storage Water	FIB	42.9%	40.0%	0%	66.7%
		RuBac	28.6%	0%	-	16.7%
		HuBac	42.9%	0%	-	16.7%
	Pipe Water Supply	FIB	Sample NA	0%	100%	0%
		RuBac	-	-	50.0%	-
		HuBac	-	-	50.0%	-
Soil		FIB	62.5%	87.5%	100%	100%
		RuBac	25.0%	37.5%	0%	37.5%
		HuBac	50.0%	87.5%	100%	87.5%
Food		FIB	100%	100%	100%	100%
		RuBac	0%	50.0%	40.0%	0%
		HuBac	0%	50.0%	60.0%	50.0%
Physico-chemical Properties of Water	pH		6.7 to 8.1	6.5 to 7.5	6.9 to 7.7	6.9 to 7.9
	EC, µmhos/cm		142 to 257	137 to 683	134 to 13730	376 to 1861
	TDS, mg/l		92 to 157	88 to 437	85 to 9060	230 to 1115
	Turbidity, NTU		<1 to 85	<1 to 57	2 to 73	<1 to 13
	Chloride (Cl), mg/l		8 to 29	8 to 120	16 to 5270	31 to 237
	Nitrogen (TKN), mg/l		<0.1 to 1.2	<0.1 to 3.6	<0.1 to 1.2	<0.1 to 0.90
	Phosphorous (P), mg/l		<0.05 to 0.33	<0.05 to 0.31	<0.05 to 2.8	<0.05 to 1.1
	Hardness ($CaCO_3$), mg/l		62 to 122	68 to 376	48 to 2673	29 to 428
	Alkalinity ($CaCO_3$), mg/l		68 to 111	51 to 175	51 to 496	120 to 325
	Arsenic (As), mg/l		<0.01	<0.01	<0.01 to 0.027	<0.01

Table-8 Summary of Findings: ODF Villages in Odisha

District			**Jagatsinghpur (Non-ODF)**		**Puri (Non-ODF)**	
Block			**Jagatsinghpur**		**Puri**	
Village			Rasalpur	Ningaon	Dupur	Balipatna
Is Declared ODF			No	No	No	No
HH with toilets (% coverage)			61.34	63.81	4.17	8.6
Environmental Medium			**%age of sampled sources found contaminated**			
Water	Ground Water	FIB	0 %	18.2%	25.0%	100%
		RuBac	-	9.1%	25.0%	14.3%
		HuBac	-	0%	25.0%	57.1%
	Surface Water	FIB	Sample NA	100%	100%	100%
		RuBac	-	100%	75.0%	100%
		HuBac	-	100%	25.0%	66.7%
	HH Storage Water	FIB	42.9 %	60.0%	90.9%	60.0%
		RuBac	0%	0%	72.7%	20.0%
		HuBac	28.6%	0%	45.5%	0%
	Pipe Water Supply	FIB	0%	0%	Sample NA	50.0%
		RuBac	-	-	-	0%
		HuBac	-	-	-	50.0%
Soil		FIB	50.0%	75.0%	100%	100%
		RuBac	0%	25.0%	12.5%	12.5%
		HuBac	50.0%	62.5%	87.5%	87.5%
Food		FIB	66.7%	75.0%	100%	100%
		RuBac	66.7%	25.0%	50.0%	0%
		HuBac	66.7%	50.0%	50.0%	60.0%
Physico-chemical Properties of Water	pH		6.3 to 7.0	6.7 to 7.5	6.5 to 7.0	7.0 to 7.6
	EC, µmhos/cm		126 to 503	153 to 1332	137 to 683	226 to 4410
	TDS, mg/l		82 to 322	98 to 786	88 to 437	180 to 2690
	Turbidity, NTU		<1 to 317	<1 to 22	<1 to 57	<1 to 32
	Chloride (Cl), mg/l		8 to 58	6 to 144	8 to 120	31 to 660
	Nitrogen (TKN), mg/l		<0.1 to 0.5	<0.1 to 2.2	<0.1 to 3.6	0.20 to 0.60
	Phosphorous (P), mg/l		<0.05 to 1.5	<0.05 to 2.9	<0.05 to 0.3	<0.05 to 9.3
	Hardness ($CaCO_3$), mg/l		44 to 174	51 to 341	68 to 376	91 to 832
	Alkalinity ($CaCO_3$), mg/l		60 to 169	81 to 501	51 to 175	11 to 753
	Arsenic (As), mg/l		<0.01	<0.01	<0.01	<0.01

4. Study Outcome : Bihar

4.1 Description of Villages Selected for Study in Bihar

The profile of villages selected from ODF and non-ODF blocks of Bihar, is illustrated below:

Table-9 Profile of villages in ODF blocks of Bihar

State	**Bihar : ODF**			
District	**Rohtas**			
Block	**Nasriganj**	**Sanjauli**	**Chenari**	**Suryapura**
Village	Beredih	Amaithi	Malhipur	Kailani
Total Population	1251	3228	5382	1568
Is Declared ODF	Yes	Yes	Yes	Yes
Is Verified ODF	Yes	Yes	Yes	Yes
Total HH	201	474	935	225
HH with Toilets	201	474	935	225
HH accessing CAOT	0	0	0	0
Remaining HH	0	0	0	0
% coverage	100	100	100	100

CAOT: Community and Other Toilets

Table-10 Profile of villages in non-ODF blocks of Bihar

State	**Bihar : non-ODF**			
District	**Patna**			
Block	**Paliganj**	**Naubatpur**	**Masaurhi**	**Dhanaura**
Village	Chiksi	Jamalpura	Nura	Raipura
Total Population	2056	1917	1103	622
Is Declared ODF	No	No	No	No
Is Verified ODF	No	No	No	No
Total HH	296	307	215	113

4.2 Landuse of ODF and non-ODF villages in study area of Bihar

66.5% to 94.5% area in ODF villages and 80.2 to 90.1% area in non-ODF villages, is under Agricultural Use (Net Sown Area), whereas 5.5% to 33.5% area in ODF villages and 9.9% to 19.8% area in non-ODF villages is under Non-agricultural Use.

Figure-26 Landuse in the study area (ODF and non-ODF villages of Bihar)

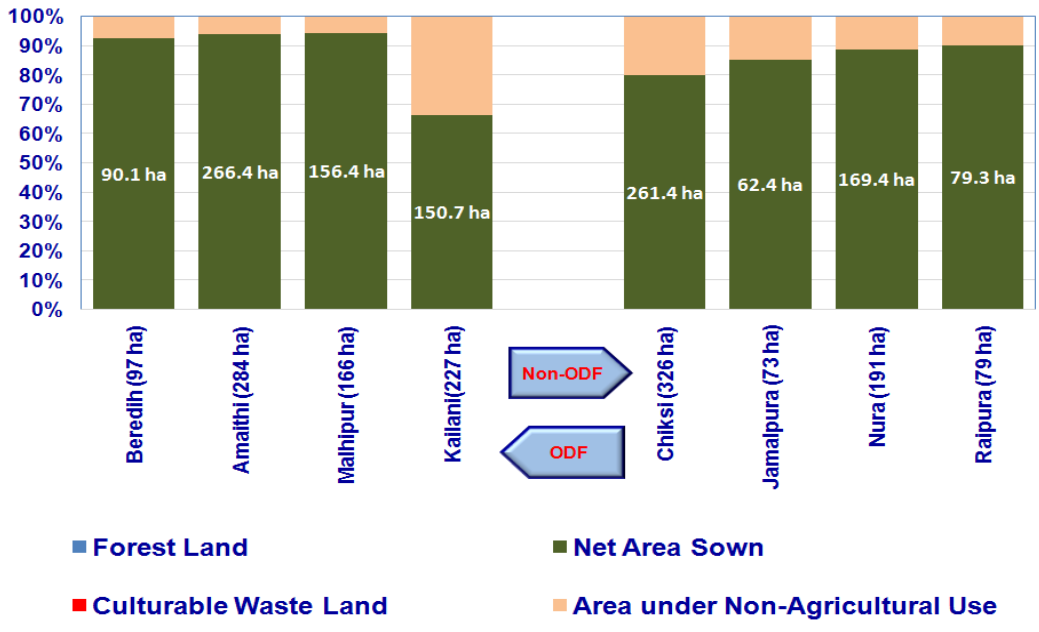
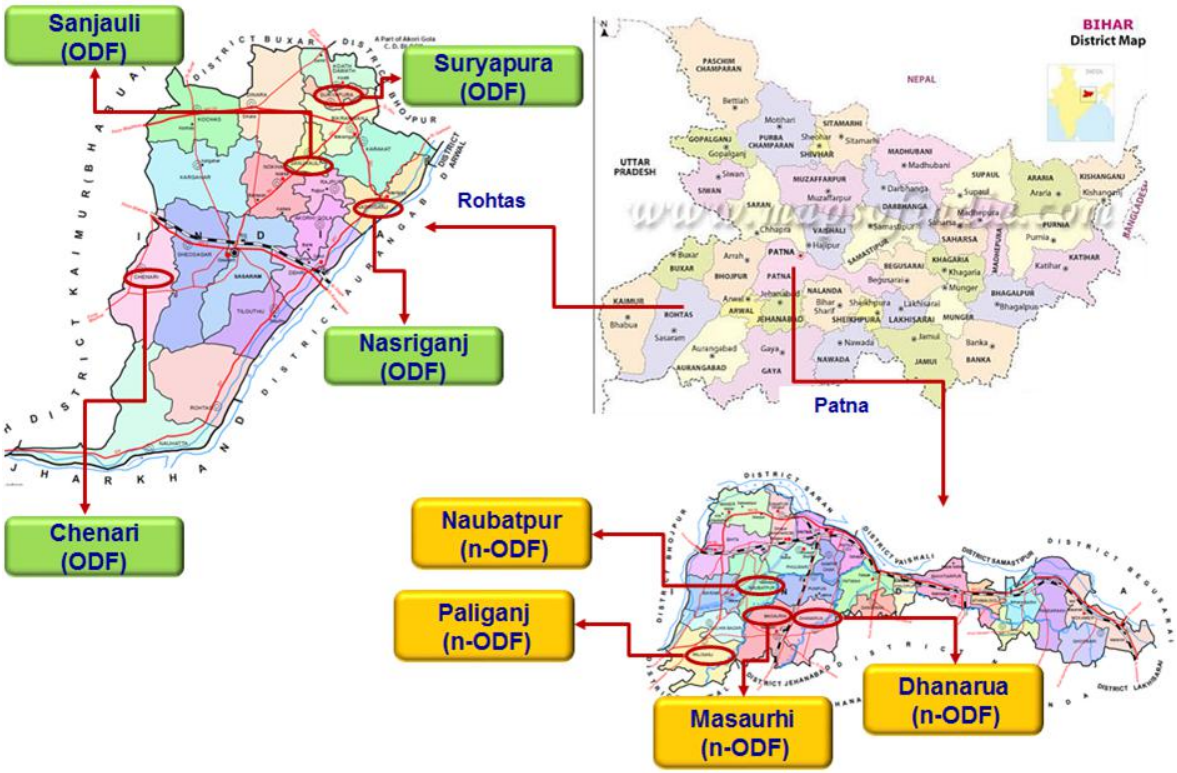


Figure-27 Study Areas in Bihar



4.3 Summary of Sample Collection from Bihar

Summary of samples collection from Bihar is described in following table.

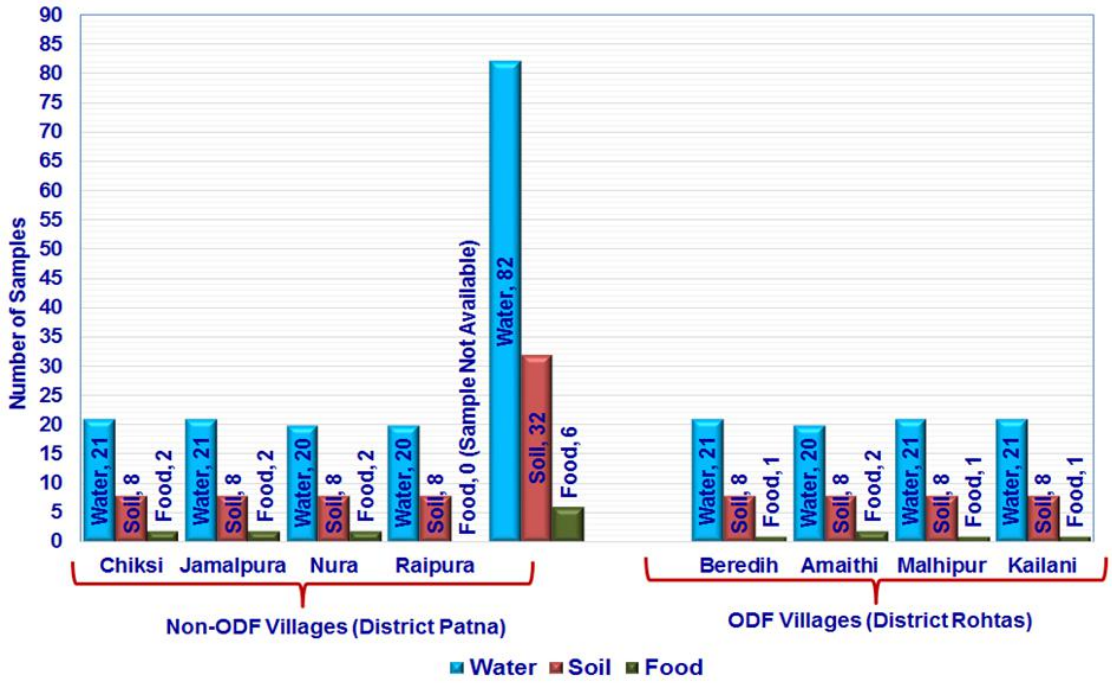
Table-11 Summary of Samples Collection from Bihar

District	Block	GP	Village	DOS	Environmental Medium			
					Water	Soil	Food	Total
Rohtas : ODF	Nasriganj	Dehari	Beredih	09.01.19	21	08	01	30
	Sanjauli	Amaithi	Amaithi	09.01.19	20	08	02	30
	Chenari	Malhipur	Malhipur	09.01.19	21	08	01	30
	Suryapura	Sheobehar	Kailani	10.01.19	21	08	01	30
Patna : n-ODF	Paliganj	Chiksi	Chiksi	08.01.19	21	08	02	31
	Naubatpur	Jamalpura	Jamalpura	08.01.19	21	08	02	31
	Masaurhi	Nura	Nura	08.01.19	20	08	02	30
	Dhanarua	Dewas	Raipura	08.01.19	20	08	00	28
Total					**165**	**64**	**11**	**240**

Remarks

As most of schools and Anganwadi centre were closed due to vacations, food samples were collected, wherever these were available.

Figure-28 Village wise spectrum of samples collected in Bihar



4.4 Rainfall Conditions at Site

No rainfall notices during the sampling period.

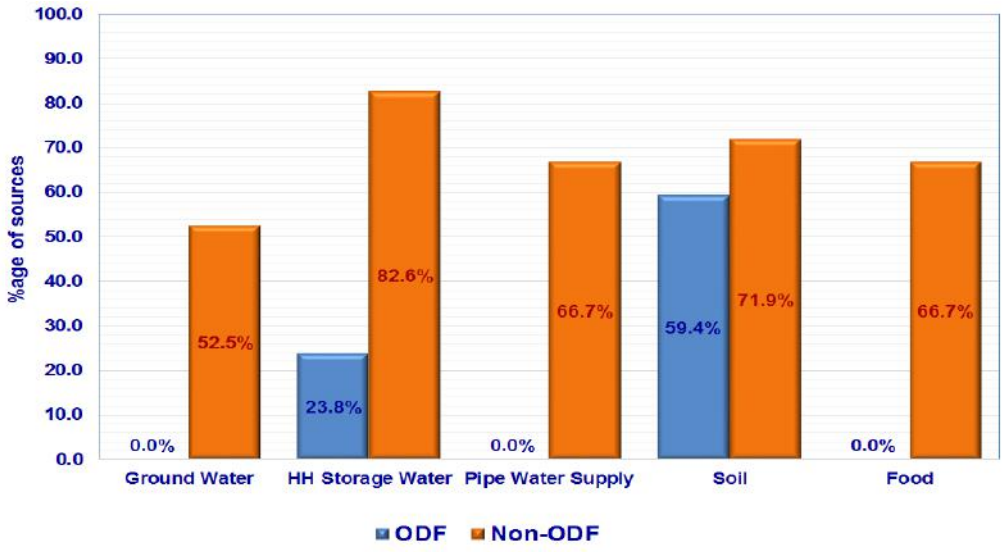
4.5 Summary of Study Outcome: Bihar

Study findings with respect to (i) Faecal Indicator Bacteria [Faecal coliform, Organisms (MPN/100 ml in case of water and MPN/g in case of soil and food), Escherichia coli (cfu/100 ml in case of water and cfu/g in case of soil and food) and Enterococci (cfu/100 ml in case of water and cfu/g in case of soil and food)]; (ii) Bacteroidales molecular markers (a) HuBac and (b) RuBac and (iii) Physico-chemical properties of water in Odisha, are presented in table-11 and 12. Detailed study results are given in the Annexure. The study can be summed up as follows.

(A) Risk of Faecal Contamination of ODF and non-ODF villages

(a) 51 numbers of groundwater sources were analysed in ODF villages, whereas in non-ODF villages, number of groundwater sample analysed were 40. In ODF villages, none of the groundwater source was found contaminated with FIB, whereas in non-ODF villages 52.5% sources were found contaminated.

Figure-29 %age of sources contaminated with FIB in Bihar



(b) 07 numbers of surface water sources were analysed in ODF villages, whereas in non-ODF villages, number of surface water samples analysed were 13. In ODF villages, 71.4% sources were found contaminated, whereas in non-ODF villages, 100% sources were estimated contaminated with FIB.

(c) The FIB contamination in Household Storage water was found in 23.8% of samples, in case of ODF villages (21number of samples were analysed), whereas the contamination found in 82.6% samples in case of non-ODF villages (23 number of samples were analysed).

(d) PWS water samples numbering to 04 were analysed in ODF villages, where none was found contaminated with FIB, whereas in case of non-ODF villages, contaminated samples percentage was 66.7% (number of samples analysed were 06).

(e) In case of soil, 32 number of samples were analysed both in ODF and non-ODF villages. 59.4% and 71.9% samples, were found contaminated with FIB in ODF and non-ODF villages respectively.

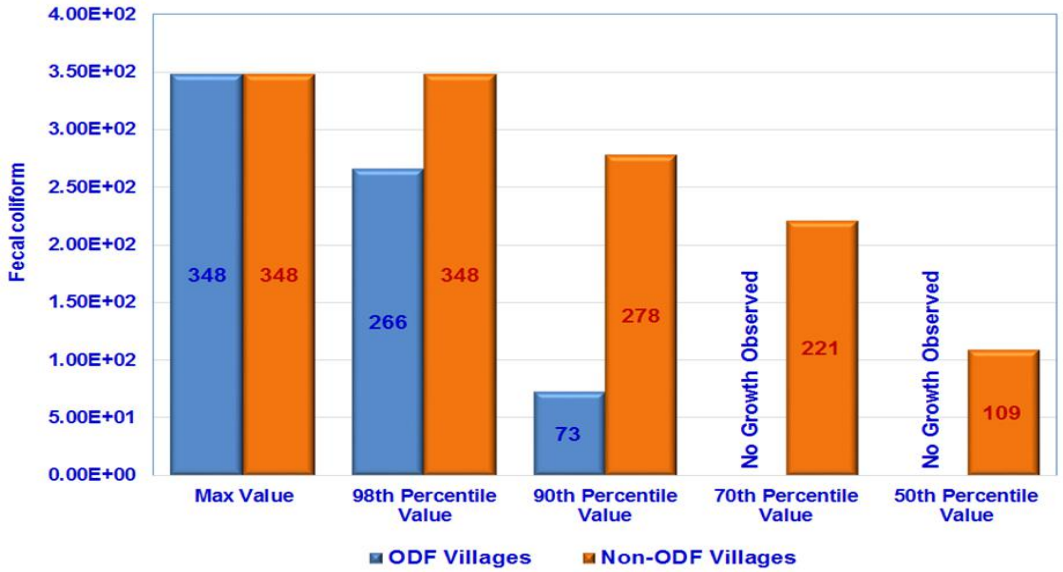
(f) In case of food samples, 05 numbers of samples were analysed in ODF and 06 numbers in non-ODF villages. None of the sample was found contaminated in ODF villages, whereas 66.7% found contaminated in non-ODF villages.

The risk of faecal contamination in non-ODF villages in comparison to ODF villages was found to be, 53.6 times more likely in case of groundwater; 1.35 times more likely in case of surface water; 3.47 times more likely in case of household storage water; 5.33 times more likely in case of piped water supply; 1.21 times more likely in case of soil; and 6.67 times more likely in case of food.

(B) Faecal Indicator Bacteria in Water

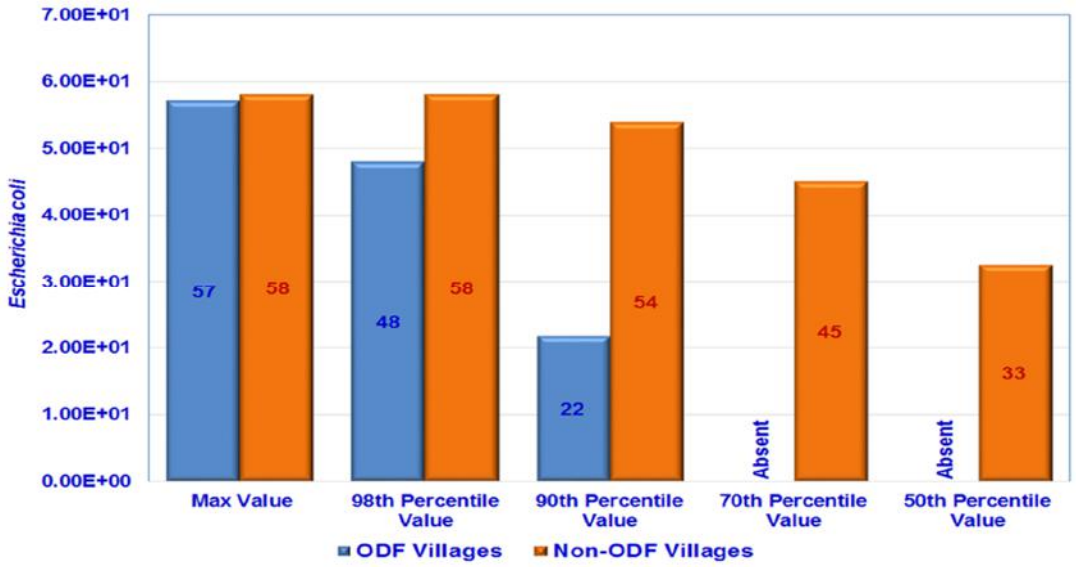
(a) Maximum values of faecal coliform, in water both from ODF and non-ODF villages, were observed 348 Organisms (MPN coliform/ 100 ml). The 70th percentile onward values of faecal coliform in water samples of ODF villages showed “No Growth”.

Figure-30 Faecal coliform, Organisms (MPN coliform/ 100 ml) in water



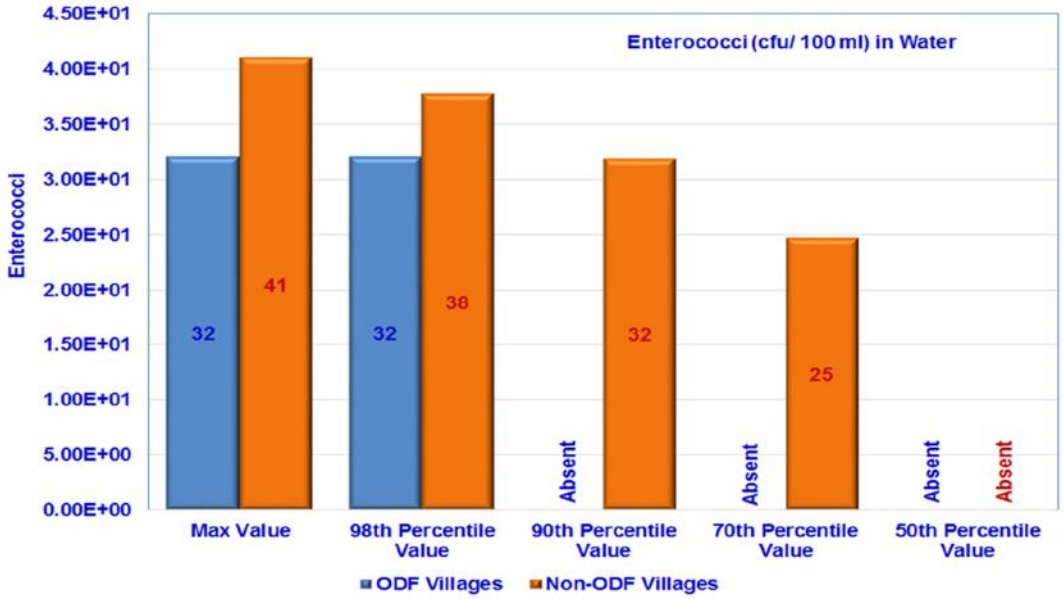
(b) Maximum values of *Escherichia coli*, in water of ODF and non-ODF villages, were observed 57 cfu/ 100 ml and 58 cfu/ 100 ml respectively. The 70th percentile onward values of *Escherichia coli* in water samples of ODF villages were found "Absent".

Figure-31 *Escherichia coli* (cfu/ 100 ml) in water



(c) Maximum values of *Enterococci*, in water of ODF and non-ODF villages, were observed 32 cfu/ 100 ml and 41 cfu/ 100 ml. The 90th percentile onward values of *Enterococci* in water samples of ODF villages were found "Absent".

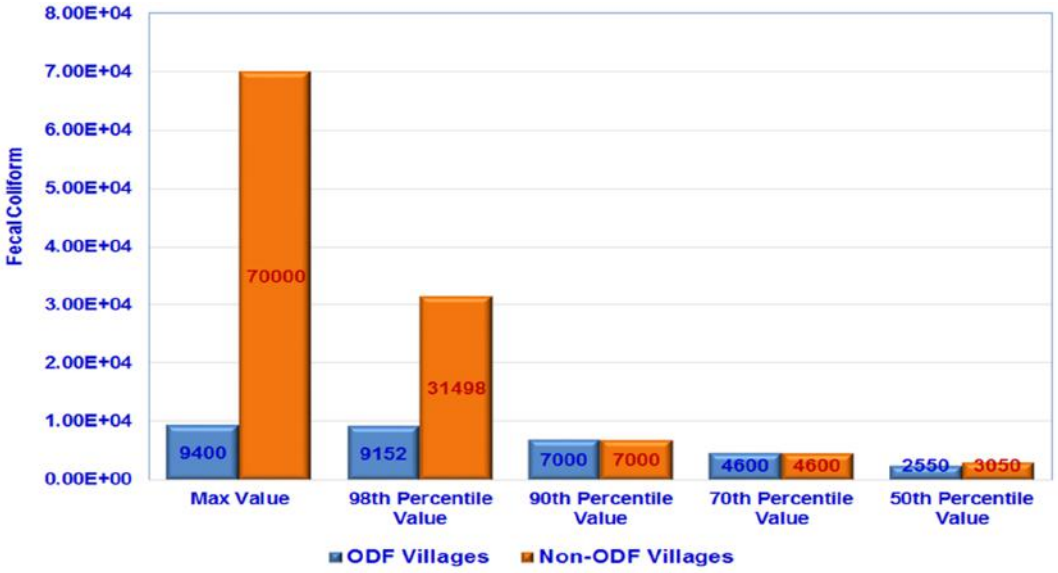
Figure-32 Enterococci (cfu/ 100 ml) in water



(C) Faecal Indicator Bacteria in Soil

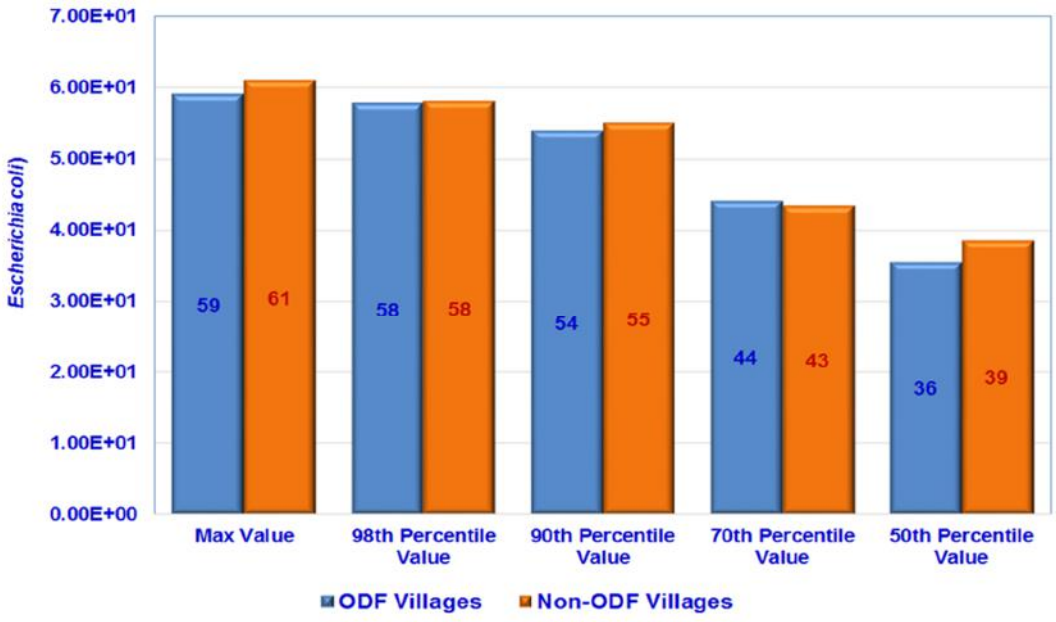
(a) Soil in ODF and non-ODF villages was found contaminated with faecal coliform with maximum value 9400 organism (MPN coliform/g) in ODF and 70000 organisms (MPN coliform/g) in non-ODF villages.

Figure-33 Faecal coliform, Organisms (MPN coliform/ g) in soil



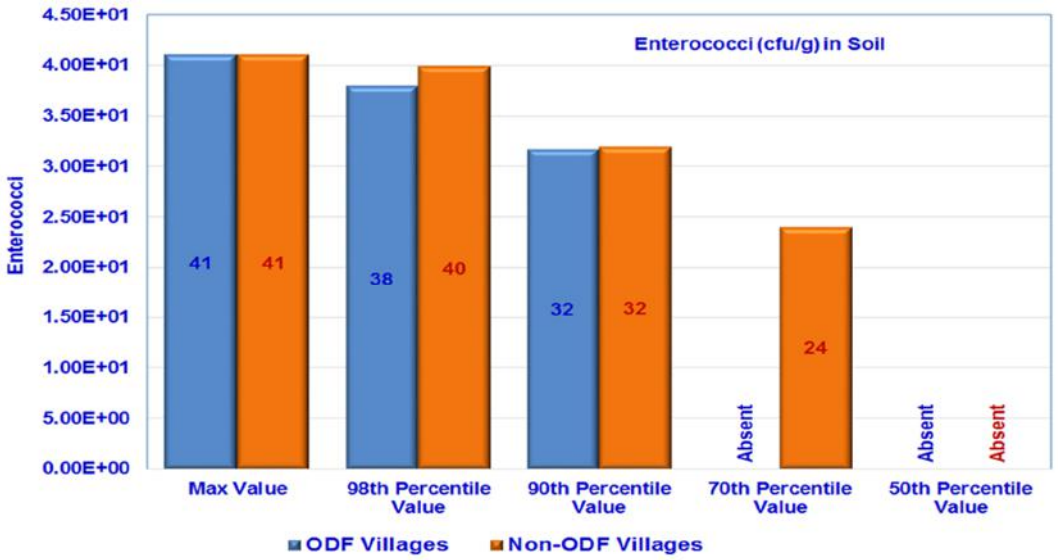
(b) Maximum values of *Escherichia coli*, in soil samples collected from ODF and non-ODF villages, were observed 59 cfu/g and 61 cfu/g respectively. The 50th percentile values in ODF and non-ODF villages, were observed 36 cfu/ g and 39 cfu/ g respectively.

Figure-34 *Escherichia coli* (cfu/ g) in soil



(c) Maximum values of *Enterococci*, in soil samples collected from both ODF and non-ODF villages, were observed 41 cfu/g. The 70th percentile onward values both in ODF and 50th percentile value both in ODF and non-ODF villages, were observed "Absent".

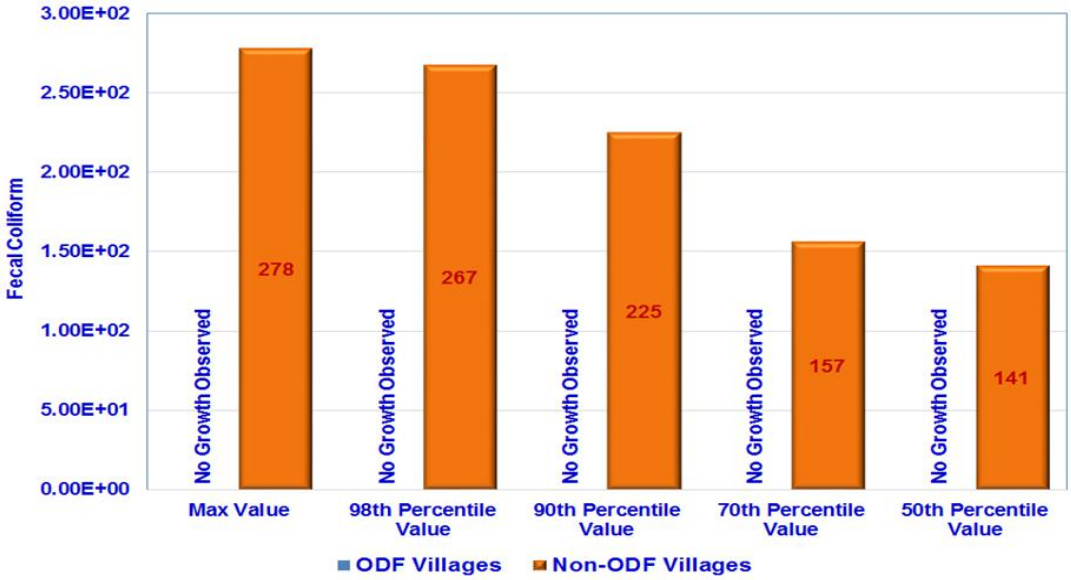
Figure-35 *Enterococci* (cfu/ g) in soil



(D) Faecal Indicator Bacteria in Food

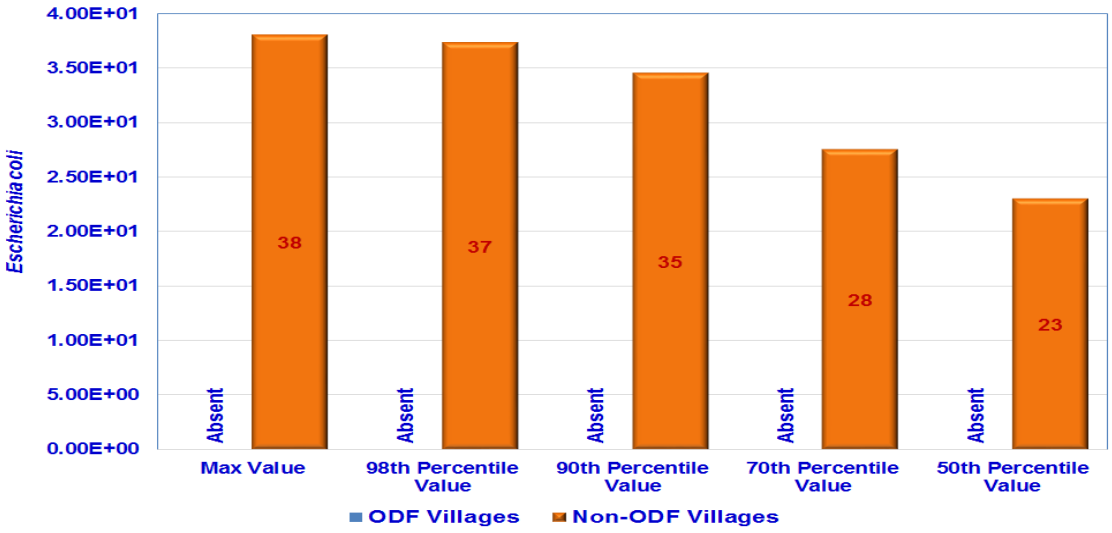
(a) No Growth Observed with respect to Faecal coliform, Organisms (MPN coliform/g) in case of food samples taken from ODF villages.

Figure-36 Faecal coliform, Organisms (MPN coliform/ g) in food



(b) *Escherichia coli*, in food samples taken from ODF villages were found "Absent".

Figure-37 *Escherichia coli* (cfu/ g) in food

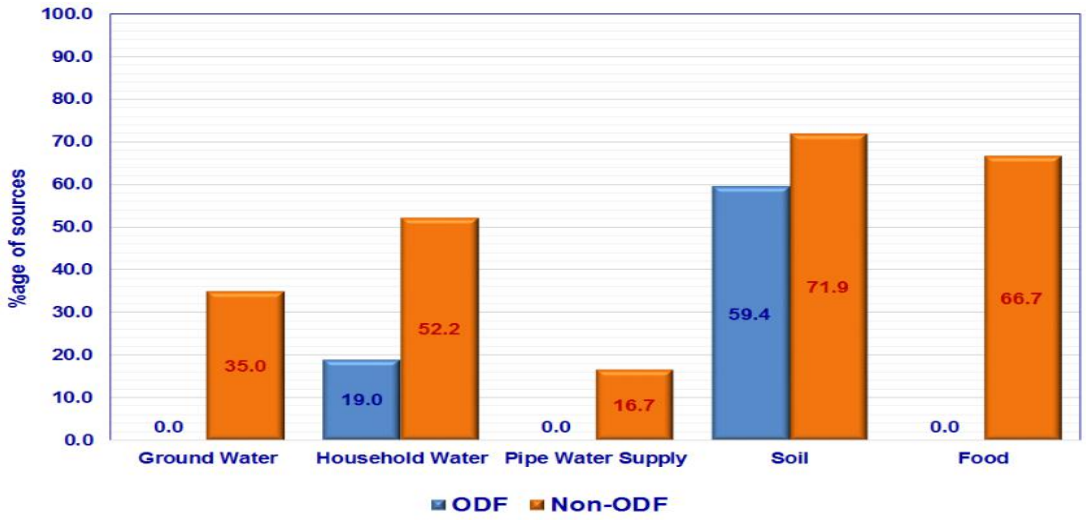


(c) Enterococci, in case of food samples taken both from ODF and non-ODF villages were found "Absent".

(E) Risk of ODF and non-ODF villages due to Faecal Contamination of Human Origin

The risk of faecal contamination due to human origin (HuBac) in non-ODF villages in comparison to ODF villages was found to be, 35.7 times more likely in case of groundwater; 1.48 times more likely in case of surface water; 2.74 times more likely in case of household storage water; 1.33 times more likely in case of piped water supply; 1.21 times more likely in case of soil; and 6.67 times more likely in case of food.

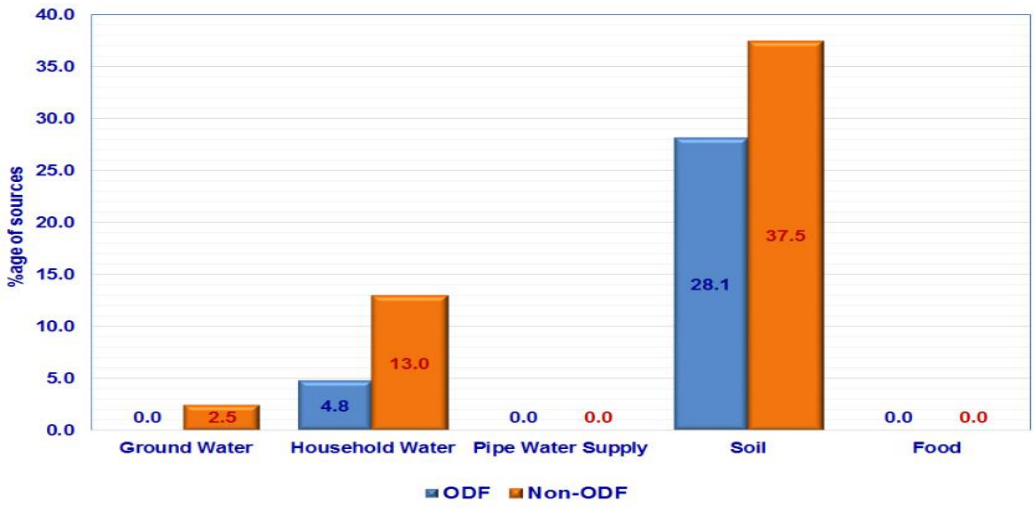
Figure-38 Faecal contamination due to Human Origin



(F) Risk of ODF and non-ODF villages due to Faecal Contamination of Animal Origin

The risk of faecal contamination due to animal origin (RuBac) in non-ODF villages in comparison to ODF villages was found to be, 2.55 times more likely in case of groundwater; 3.77 times more likely in case of surface water; 2.74 times more likely in case of household storage water; 0.67 times more likely in case of piped water supply; 1.33 times more likely in case of soil; and 0.83 times more likely in case of food.

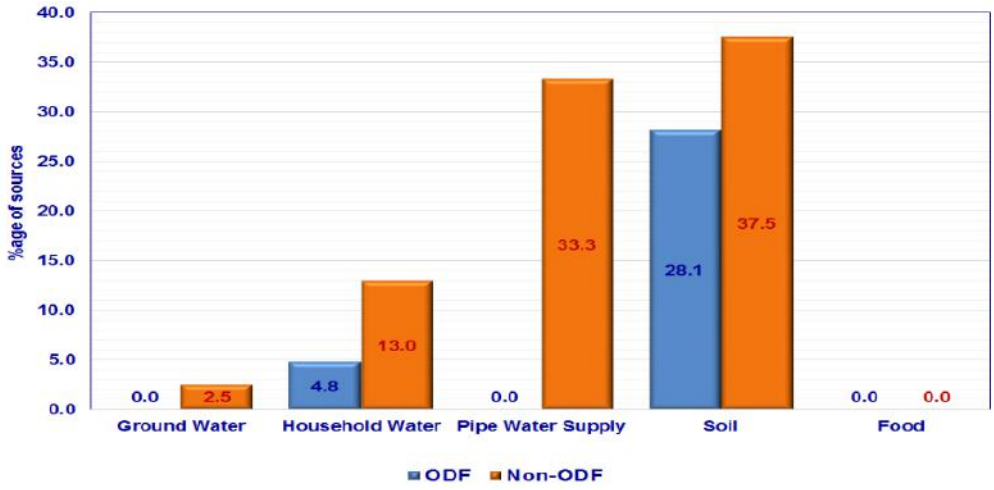
Figure-39 Faecal contamination due to Animal Origin



(G) Risk of ODF and non-ODF villages due to Faecal Contamination of both Human and Animal Origin

The risk of faecal contamination both due to human origin (HuBac) and animal origin (RuBac) in non-ODF villages in comparison to ODF villages was found to be, 2.55 times more likely in case of groundwater; 3.77 times more likely in case of surface water; 2.74 times more likely in case of household storage water; 2.67 times more likely in case of piped water supply; 1.33 times more likely in case of soil; and 0.83 times more likely in case of food.

Figure-40 Faecal contamination both due to Human and Animal Origin



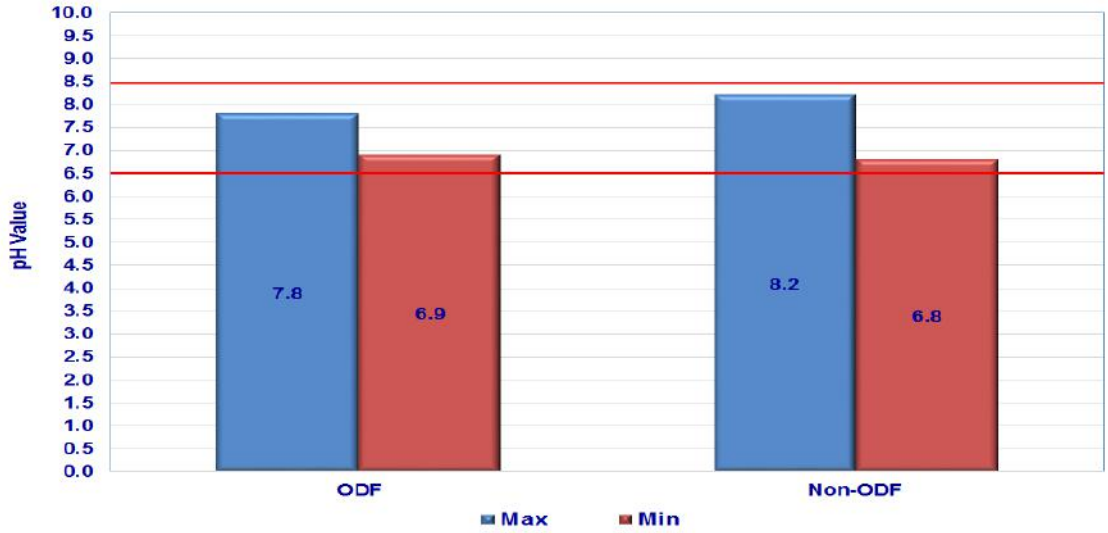
(H) Physico-chemical Properties of Water Sources in ODF and non-ODF villages

(Acceptable and maximum permissible, wherever available, are shown by red lines on the graph)

(a) pH value of water

pH value was found ranging between 6.9 to 7.8 in water samples from ODF villages and 6.8 to 8.2 in water samples from non-ODF villages, which indicates normal pH level.

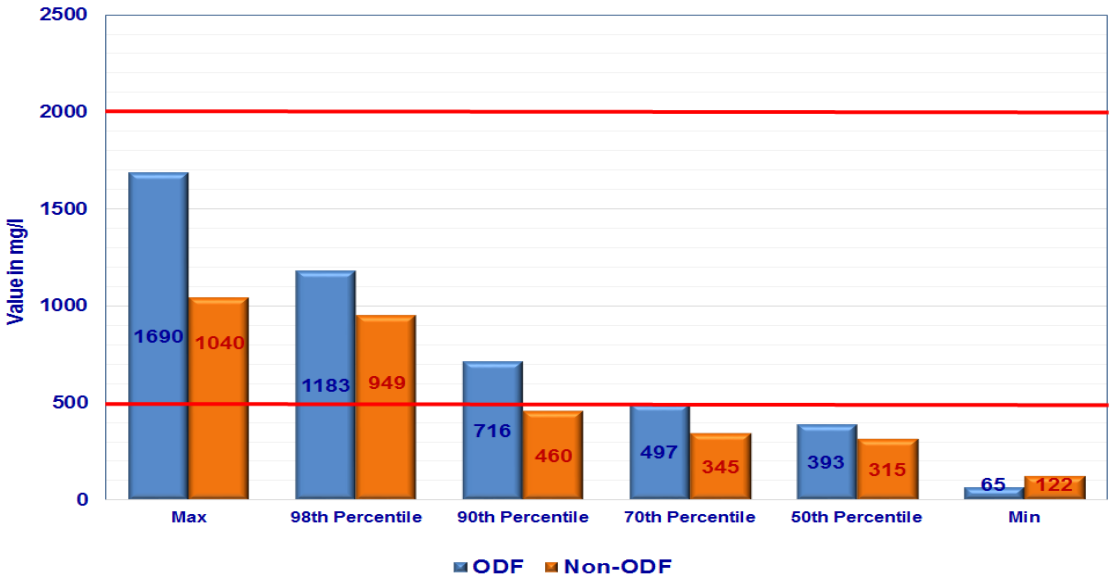
Figure-41 pH value of Water



(b) Total Dissolved Solids (TDS) in water

TDS was found ranging between 65 to 1690 mg/l in ODF villages and 122 to 1040 mg/l in non-ODF villages. 100% samples were found within the permissible limit of TDS in water.

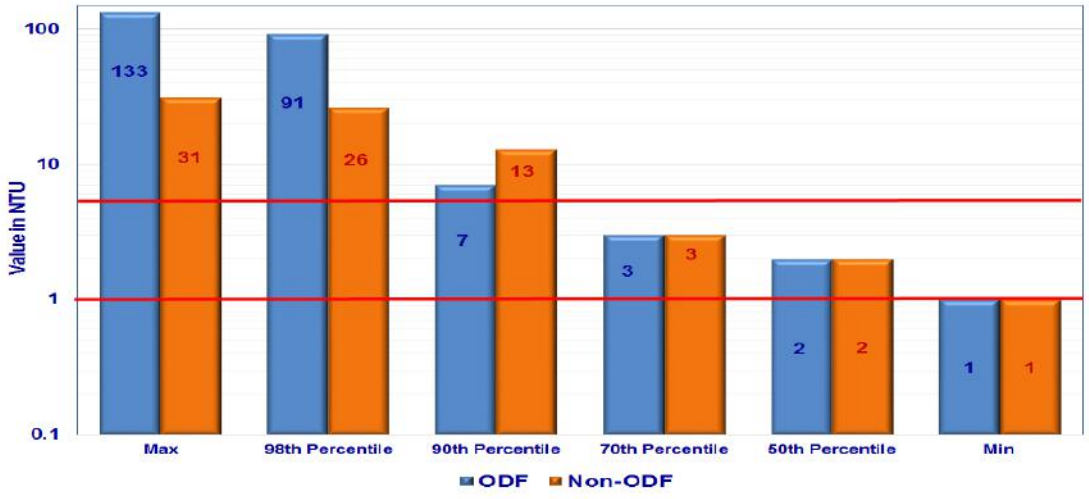
Figure-42 Total Dissolved Solids (TDS) in Water



(c) Turbidity in water

Turbidity was found ranging between 1 to 133 NTU in water samples of ODF villages and between 1 to 31 NTU in water samples of non-ODF villages. 70th percentile onwards values of turbidity in water of both ODF and non-ODF villages, was observed within the permissible limits.

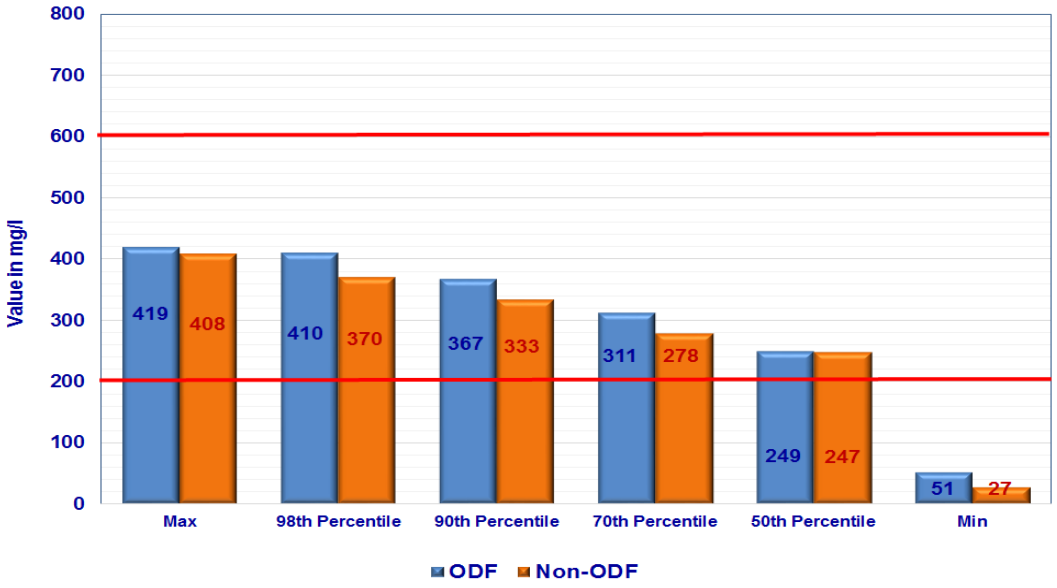
Figure-43 Turbidity in Water



(d) Total Alkalinity in water

Total Alkalinity as $CaCO_3$ was found ranging between 51 to 419 mg/l in ODF villages and 27 to 408 mg/l in non-ODF villages. 100% samples were found within the permissible limit of Total Alkalinity in water.

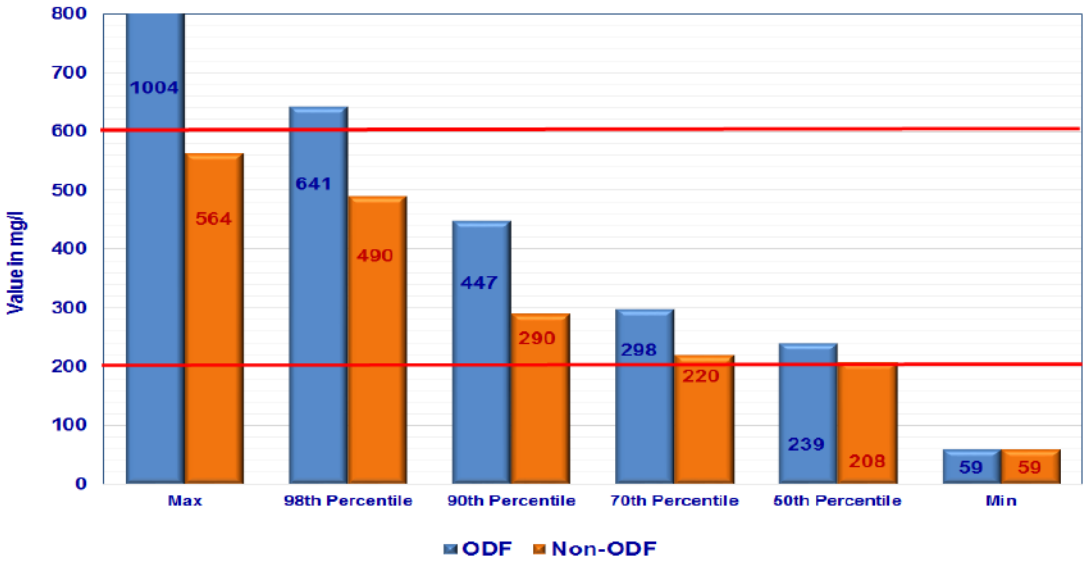
Figure-44 Total Alkalinity in Water



(e) Total Hardness in water

Total Hardness as $CaCO_3$ was found ranging between 59 to 1004 mg/l in ODF villages and 59 to 564 mg/l in non-ODF villages. The 90th percentile onward values of total hardness were found within the permissible limits of drinking water.

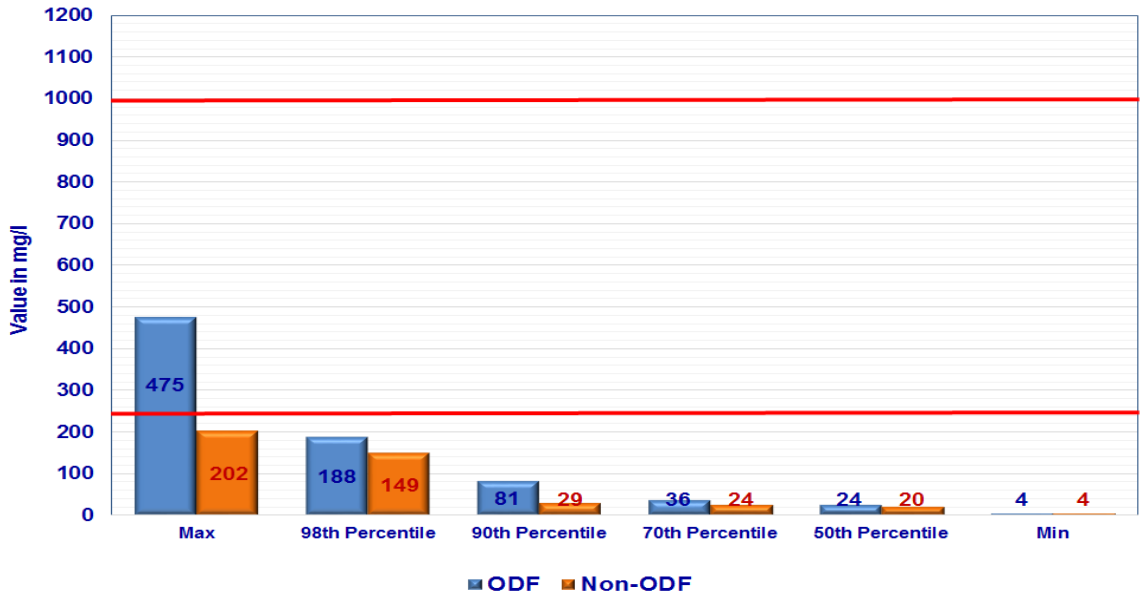
Figure-45 Total Hardness in Water



(f) Chlorides in water

Chloride as Cl was found ranging between 4 to 475 mg/l in ODF villages and 4 to 202 mg/l in non-ODF villages. 100% samples were found within the permissible limit of Chlorides in water.

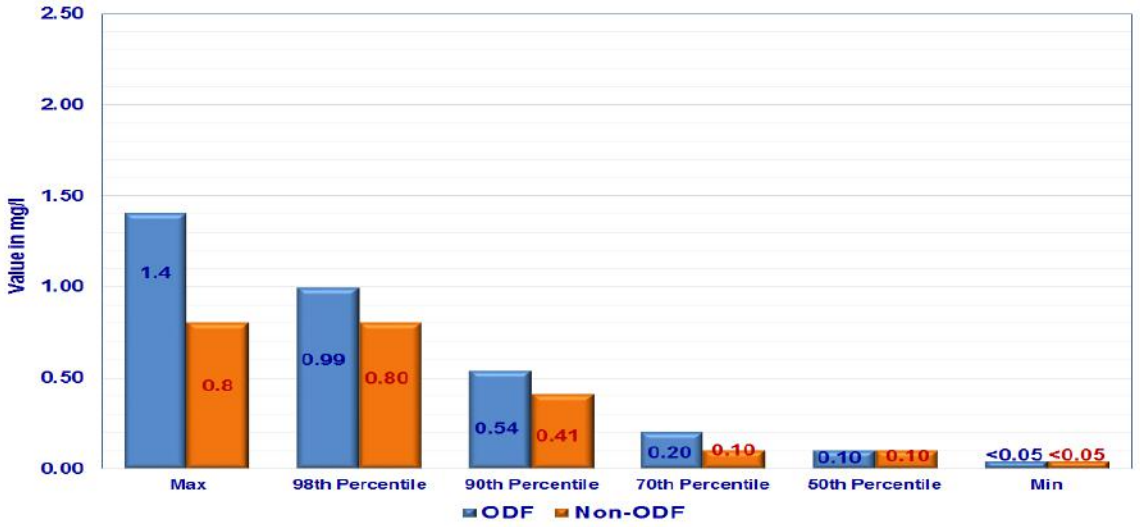
Figure-46 Chlorides in Water



(g) Total phosphorous in water

Phosphorous as P is estimated <0.05 to 1.4 mg/l in ODF villages and <0.05 to 0.8 mg/l in non-ODF villages. The 98th percentile onward values of phosphorous are found below 1.0 mg/l.

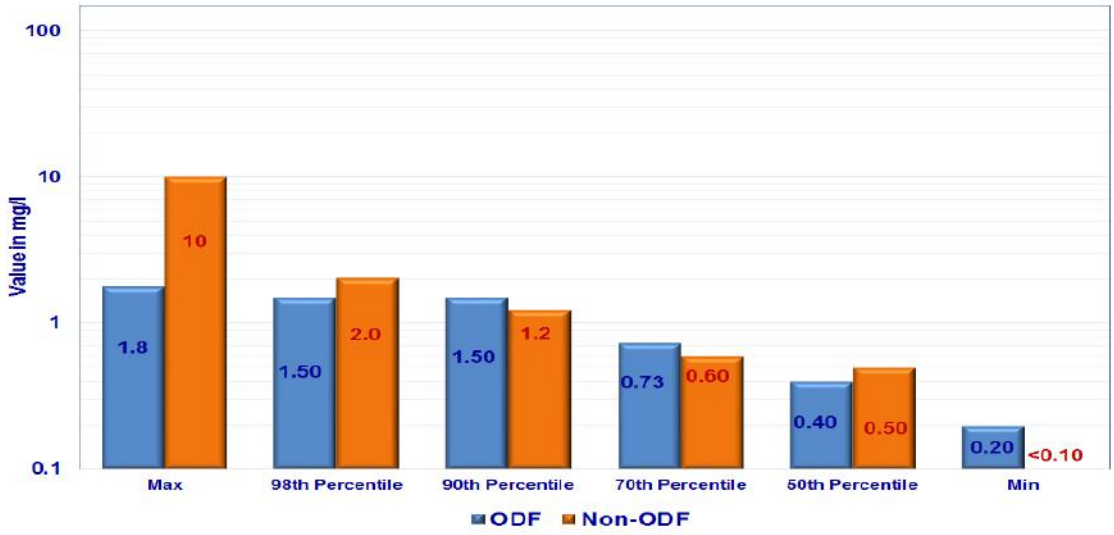
Figure-47 Total phosphorous in water



(h) Total Kjeldahl Nitrogen in water

Total Nitrogen as N were found ranging between 0.20 to 1.8 mg/l in ODF villages and <0.10 to 10 mg/l in non-ODF villages. The 70th percentile onward values of nitrogen were found below 1.0 mg/l.

Figure-48 Total Nitrogen in water



(i) Arsenic in water

Arsenic as As is “Not Detected” (Detection Limit 0.01 mg/l) in any of the sample drawn from ODF and non-ODF villages.

Table-12 Summary of Findings: ODF Villages in Bihar

District			**Rohtas (ODF)**			
Block			Nasariganj	Sanjauli	Chenari	Suryapura
Village			Beredih	Amaithi	Malhipur	Kailani
Is Declared ODF			Yes	Yes	Yes	Yes
HH with toilets (% coverage)			100	100	100	100
Environmental Medium			**%age of sampled sources found contaminated**			
Water	Ground Water	FIB	0 %	0%	0%	0%
		RuBac	-	-	-	-
		HuBac	-	-	-	-
	Surface Water	FIB	50.0 %	100%	75.0%	Sample NA
		RuBac	50.0%	0%	25.0%	-
		HuBac	0%	0%	75.0%	-
	HH Storage Water	FIB	40.0 %	20.0%	0%	40.0%
		RuBac	0%	20.0%	-	0%
		HuBac	20.0%	20.0%	-	40.0%
	Pipe Water Supply	FIB	Sample NA	0%	0%	Sample NA
		RuBac	-	-	-	-
		HuBac	-	-	-	-
Soil		FIB	62.5%	62.5%	50.0%	62.5%
		RuBac	37.5%	25.0%	25.0%	25.0%
		HuBac	62.5%	62.5%	50.0%	62.5%
Food		FIB	0%	0%	0%	0%
		RuBac	-	-	-	-
		HuBac	-	-	-	-
Physico-chemical Properties of Water	pH		7.1 to 7.7	7.0 to 7.3	6.9 to 7.8	7.0 to 7.5
	EC, µmhos/cm		185 to 1131	149 to 1730	101 to 2533	354 to 1961
	TDS, mg/l		120 to 700	100 to 1124	65 to 1690	230 to 1265
	Turbidity, NTU		1 to 3	1 to 21	1 to 33	1 to 72
	Chloride (Cl), mg/l		8 to 91	4 to 186	8 to 475	12 to 55
	Nitrogen (TKN), mg/l		0.3 to 0.7	1.0 to 1.5	0.2 to 1.8	<0.1 to 1.00
	Phosphorous (P), mg/l		<0.05 to 0.60	<0.05 to 1.4	<0.05 to 0.53	<0.05 to 0.30
	Hardness ($CaCO_3$), mg/l		98 to 447	129 to 490	59 to 1004	153 to 686
	Alkalinity ($CaCO_3$), mg/l		55 to 412	55 to 357	51 to 419	133 to 408
	Arsenic (As), mg/l		<0.01	<0.01	<0.01	<0.01

Table-13 Summary of Findings: ODF Villages in Bihar

District			**Patna (Non-ODF)**			
Block			Paliganj	Naubatpur	Masaurhi	Dhanarua
Village			Chiksi	Jamalpura	Nura	Raipura
Is Declared ODF			No	No	No	No
HH with toilets (% coverage)			61.34	63.81	4.17	8.6
Environmental Medium			**%age of sampled sources found contaminated**			
Water	Ground Water	FIB	54.6 %	50.0%%	55.6%	50.0%
		RuBac	0%	0%	11.1%	0%
		HuBac	27.3%	25.0%	44.4%	50.0%
	Surface Water	FIB	100%	Sample NA	100%	100%
		RuBac	66.7%	-	40%	60.0%
		HuBac	66.7%	-	100%	80.0%
	HH Storage Water	FIB	100%	100%	66.67%	66.7%
		RuBac	0%	33.3%	16.7%	0%
		HuBac	20.0%	50.0%	66.7%	66.7%
	Pipe Water Supply	FIB	100%	66.7%	Sample NA	0%
		RuBac	0%	0%	-	-
		HuBac	50.0%	0%	-	-
Soil		FIB	62.5%	75.0%	75.0%	75.0%
		RuBac	12.5%	75.0%	37.5%	25.0%
		HuBac	62.5%	75.0%	75.0%	75.0%
Food		FIB	100%	50.0%	50.0%	Sample NA
		RuBac	0%	0%	0%	-
		HuBac	100%	50.0%	50.0%	-
Physico-chemical Properties of Water	pH		6.8 to 7.8	7.6 to 7.9	7.6 to 8.1	7.6 to 8.2
	EC, µmhos/cm		173 to 716	403 to 1608	296 to 1589	372 to 641
	TDS, mg/l		122 to 470	260 to 1040	190 to 1030	242 to 417
	Turbidity, NTU		1 to 11	1 to 24	1 to 31	1 to 25
	Chloride (Cl), mg/l		4 to 36	12 to 202	8 to 119	16 to 28
	Nitrogen (TKN), mg/l		1 to 10	0.30 to 0.7	0.10 to 0.8	0.10 to 0.60
	Phosphorous (P), mg/l		<0.05 to 0.8	<0.05 to 0.3	<0.05 to 0.8	<0.05 to 0.2
	Hardness ($CaCO_3$), mg/l		59 to 290	141 to 564	67 to 494	129 to 263
	Alkalinity ($CaCO_3$), mg/l		27 to 310	169 to 408	82 to 380	145 to 345
	Arsenic (As), mg/l		<0.01	<0.01	<0.01	<0.01

5. Study Outcome : West Bengal

5.1 Description of Villages Selected for Study in West Bengal

The profile of villages selected from ODF and non-ODF blocks of West Bengal, is illustrated below:

Table-14 Profile of villages in ODF blocks of West Bengal

State	**West Bengal : ODF**			
District	**Haora**			
Block	**Bally-Jagacha**	**Domjur**	**Domjur**	**Panchla**
Village	Bally-CT	Oadipur	Domjur-CT	Gondalpara
Total Population	9727	5519	18442	4474
Is Declared ODF	Yes	Yes	Yes	Yes
Is Verified ODF	Yes	Yes	Yes	Yes
Total HH	2369	768	4308	1083
HH with Toilets	2369	768	4308	1083
HH accessing CAOT	0	0	0	0
Remaining HH	0	0	0	0
% coverage	100	100	100	100
ODF Declaration	09/11/2015	21/12/2015	22/11/2016	04/10/2016

CAOT: Community and Other Toilets

Table-15 Profile of villages in non-ODF blocks of West Bengal

State	**West Bengal : non-ODF**			
District	**Darjeeling**			
Block	**Gorubathan**	**Gorubathan**	**Jore Bunglow Sukhiapokhri**	**Mirik**
Village	Today tangta Khasmahal	Paten Godak Khasmahal	Mariabong Tea garden	Chota Chenga Belagachi
Total Population	5290	5530	2404	1624
Is Declared ODF	No	No	No	No
Is Verified ODF	No	No	No	No
Total HH	1031	1157	607	340

5.2 Landuse of ODF and non-ODF villages in study area of West Bengal

ODF villages are the Census Town and hence there is no agricultural land therein. 52.5 to 86.5% area in non-ODF villages, is under Agricultural Use (Net Sown Area), whereas 13.5% to 37.7% area in non-ODF villages is under Non-agricultural Use.

Figure-49 Landuse in the study area (ODF and non-ODF villages of West Bengal)

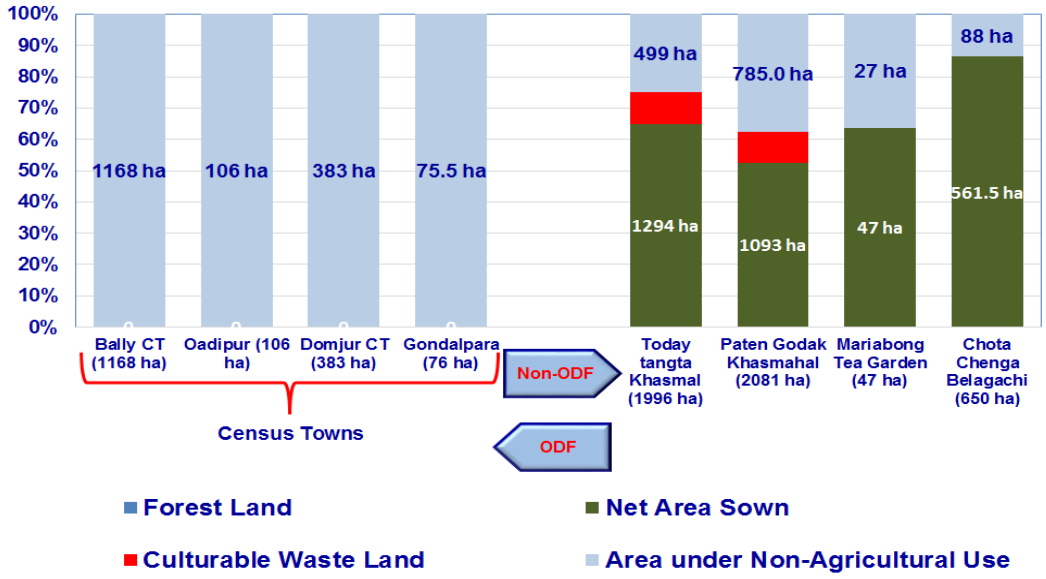
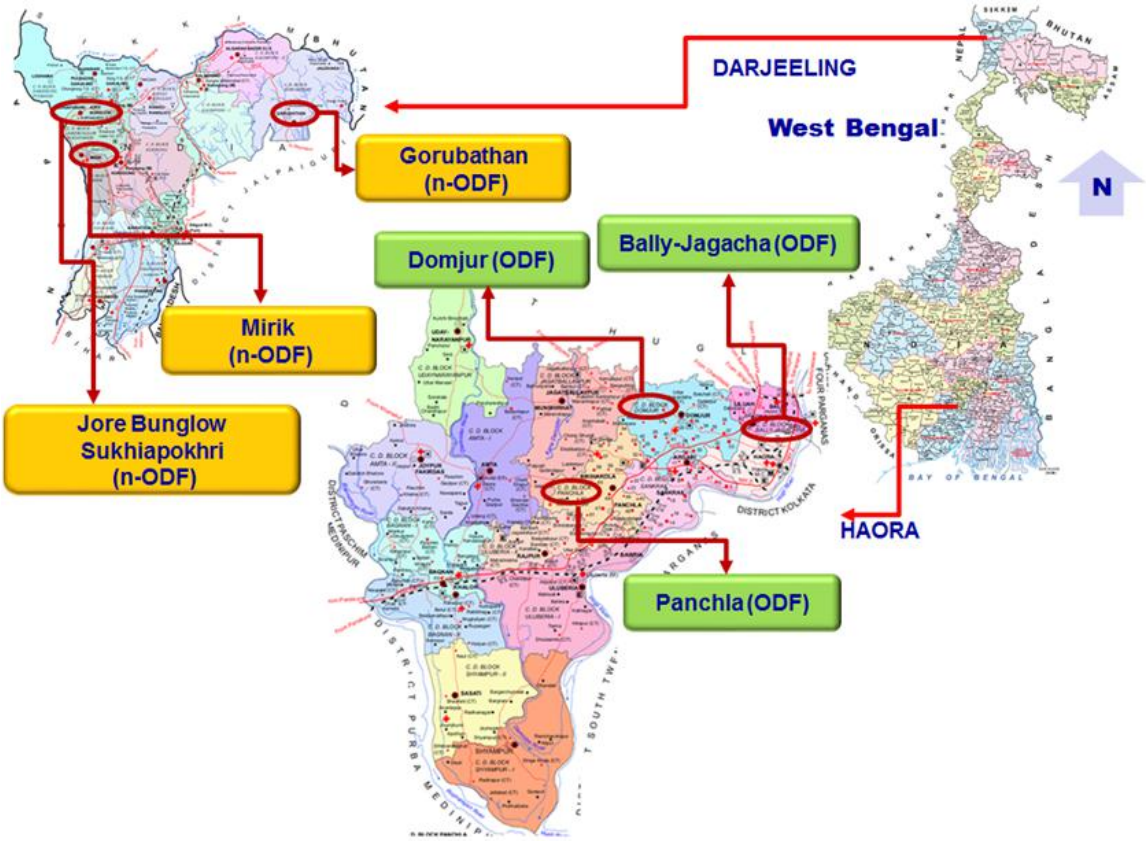


Figure-50 Study Areas in West Bengal



5.3 Summary of Sample Collection from West Bengal

Summary of samples collection from West Bengal is described in following table.

Table-16 Summary of Samples Collection from West Bengal

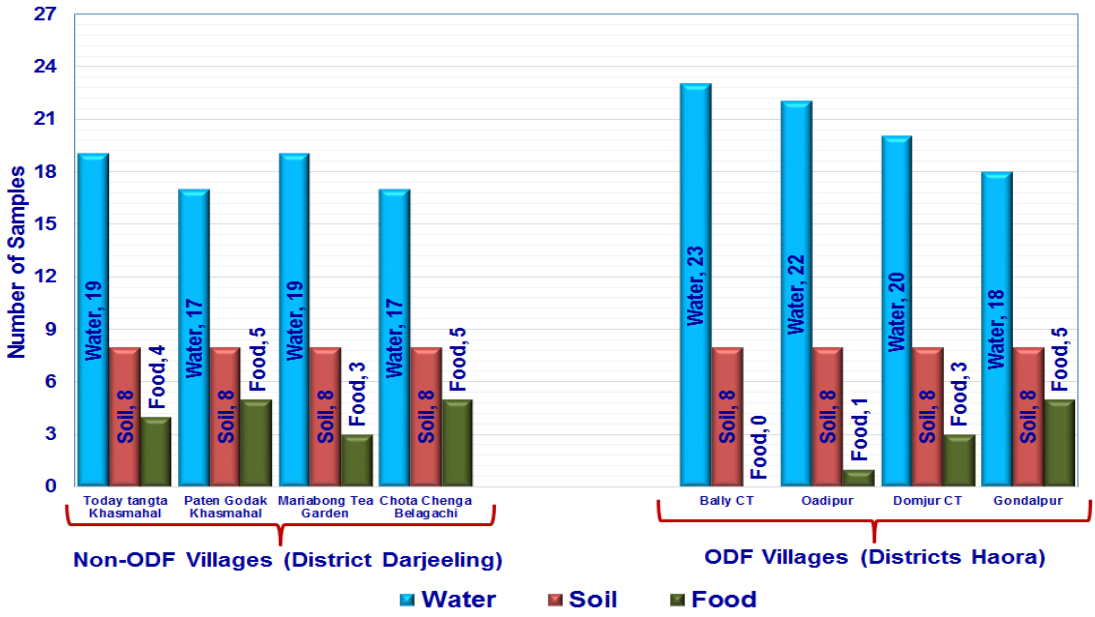
District	Block	GP	Village	DOS	Environmental Medium			
					Water	Soil	Food	Total
Haora	Bally-Jagacha	Durgapur A Nagar	Bally CT	27.12.18	23	08	0	31
	Domjur	Rudrapur	Oadipur	27.12.18	22	08	01	31
		Domjur	Domjur CT	27.12.18	12	05	02	19
				28.12.18	08	03	01	12
	Panchla	Gangadharpur	Gondalpara	27.12.18	18	08	05	31
Total					83	32	09	124

Remarks :
- As school were closed due to vacation and there was strike at Anganwadi centre, MDM was not available at all locations.
- Some school were open for extra classes from where MDM samples were taken.
- Food samples from Dhabah were taken, wherever same was available

District	Block	GP	Village	DOS	Environmental Medium			
					Water	Soil	Food	Total
Darjeeling	Gorubathan	Todeytangta	Today tangta Khasmahal	16.01.19	19	08	04	31
		Patengodak	Paten Godak Khasmahal	16.01.19	17	08	05	30
	Jore Bunglow Sukhiapokhri	Lingia Marybong	Mariabong Tea Garden	17.01.19	19	08	03	30
	Mirik	Chenga Panighata	Chota Chenga Belagachi	18.01.19	17	08	05	30

Remarks :
- Groundwater was available only in one village
- Food samples were taken, wherever same were available

Figure-51 Village wise spectrum of samples collected in West Bengal



5.4 Rainfall Conditions at Site

No rainfall notices during the sampling period.

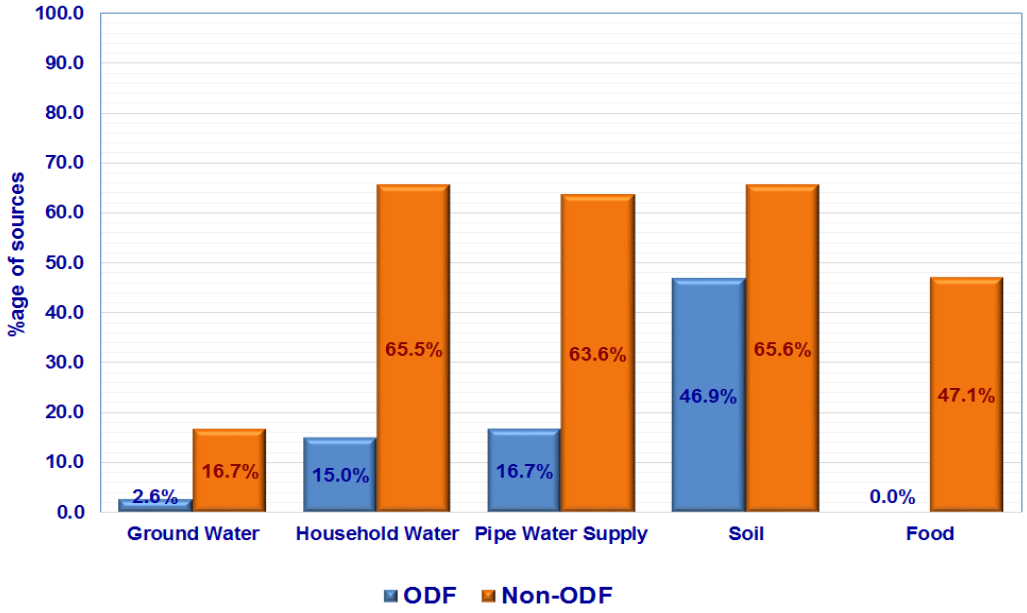
5.5 Summary of Study Outcome: West Bengal

Study findings with respect to (i) Faecal Indicator Bacteria [Faecal coliform, Organisms (MPN/100 ml in case of water and MPN/g in case of soil and food), Escherichia coli (cfu/100 ml in case of water and cfu/g in case of soil and food) and Enterococci (cfu/100 ml in case of water and cfu/g in case of soil and food)]; (ii) Bacteroidales molecular markers (a) HuBac and (b) RuBac and (iii) Physico-chemical properties of water in Odisha, are presented in table-16 and 17. Detailed study results are given in the Annexure. The study can be summed up as follows.

(A) Risk of Faecal Contamination of ODF and non-ODF villages

(a) 39 numbers of groundwater sources were analysed in ODF villages, whereas in non-ODF villages, number of groundwater sample analysed were 06. In ODF villages, 2.6% groundwater source were found contaminated with FIB, whereas in non-ODF villages 16.7% sources were found contaminated.

Figure-52 %age of sources contaminated with FIB in West Bengal



(b) 18 numbers of surface water sources were analyzed in ODF villages, whereas in non-ODF villages, number of surface water samples analyzed were 15. In ODF villages, 88.9% sources were found contaminated, whereas in non-ODF villages, 60% sources were estimated contaminated with FIB.

(c) The FIB contamination in Household Storage water was found in 15.0% of samples, in case of ODF villages (20 number of samples were analyzed), whereas the contamination found in 65.5% samples in case of non-ODF villages (20 number of samples were analyzed).

(d) PWS water samples numbering to 06 were analysed in ODF villages, where 16.7% samples were found contaminated with FIB, whereas in case of non-ODF villages, contaminated samples percentage was 63.6% (number of samples analysed were 22).

(e) In case of soil, 32 number of samples were analysed both in ODF and non-ODF villages. 46.9% and 65.6% samples, were found contaminated with FIB in ODF and non-ODF villages respectively.

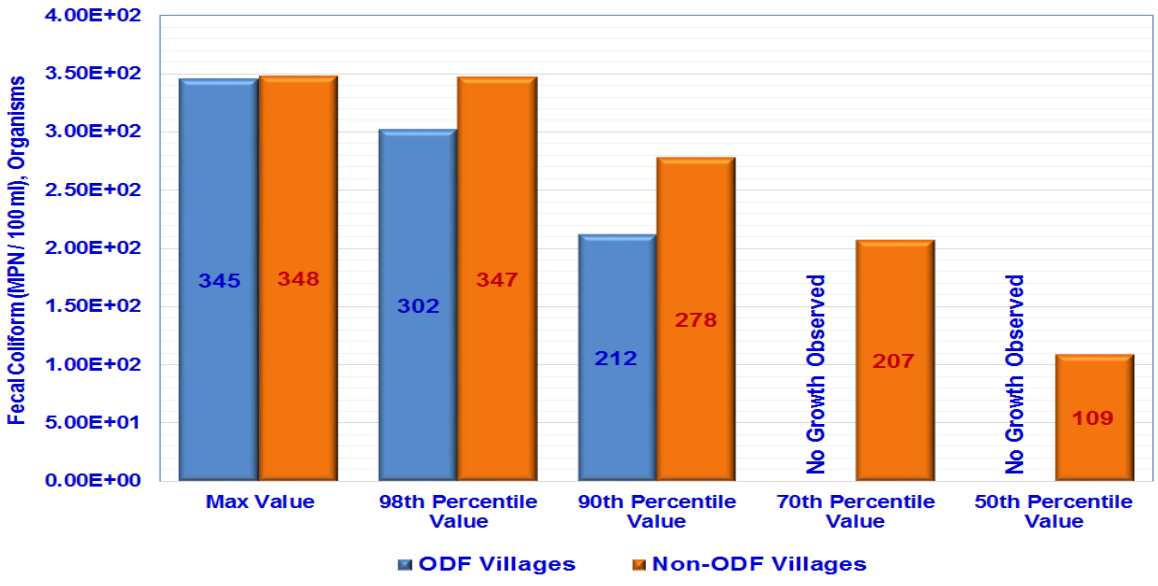
(f) In case of food samples, 09 numbers of samples were analysed in ODF and 17 numbers in non-ODF villages. None of the sample was found contaminated in ODF villages, whereas 47.1% found contaminated in non-ODF villages.

The risk of faecal contamination in non-ODF villages in comparison to ODF villages was found to be, 6.5 times more likely in case of groundwater; 0.68 times more likely in case of surface water; 4.37 times more likely in case of household storage water; 3.82 times more likely in case of piped water supply; 1.40 times more likely in case of soil; and 8.47 times more likely in case of food.

(B) Faecal Indicator Bacteria in Water

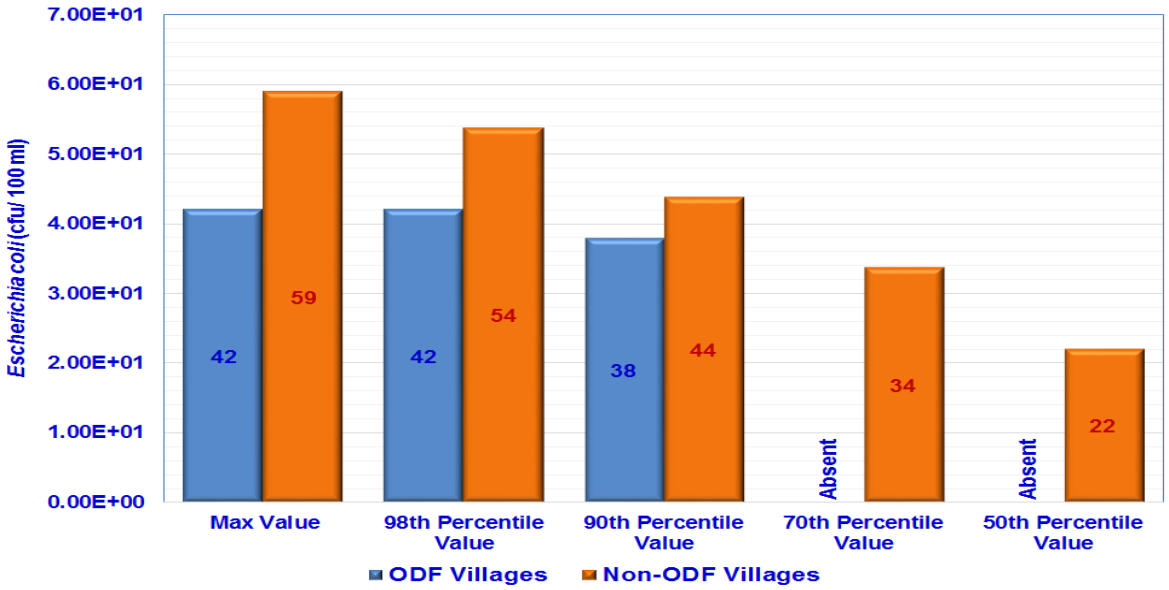
(a) Maximum values of faecal coliform, in water from ODF and non-ODF villages, were observed 345 and 348 Organisms (MPN coliform/ 100 ml) respectively. The 70th percentile onward values of faecal coliform in water samples of ODF villages showed “No Growth”.

Figure-53 Faecal coliform, Organisms (MPN coliform/ 100 ml) in water



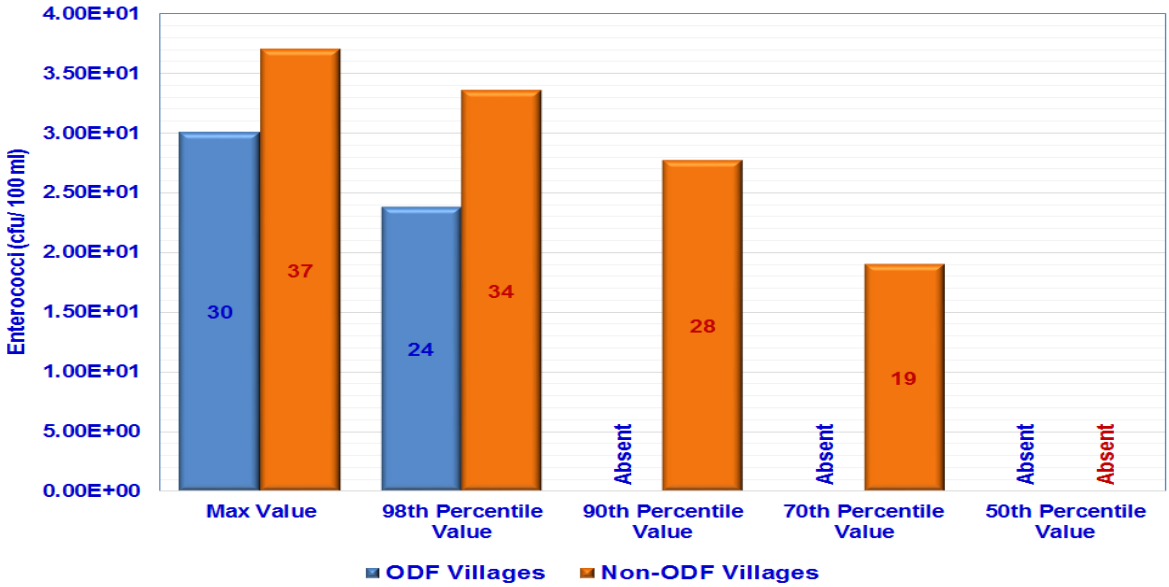
(b) Maximum values of *Escherichia coli*, in water of ODF and non-ODF villages, were observed 42 cfu/ 100 ml and 59 cfu/ 100 ml respectively. The 70th percentile onward values of *Escherichia coli* in water samples of ODF villages were found "Absent".

Figure-54 *Escherichia coli* (cfu/ 100 ml) in water



(c) Maximum values of *Enterococci*, in water of ODF and non-ODF villages, were observed 30 cfu/ 100 ml and 37 cfu/ 100 ml. The 90th percentile onward values of *Enterococci* in water samples of ODF villages were found "Absent".

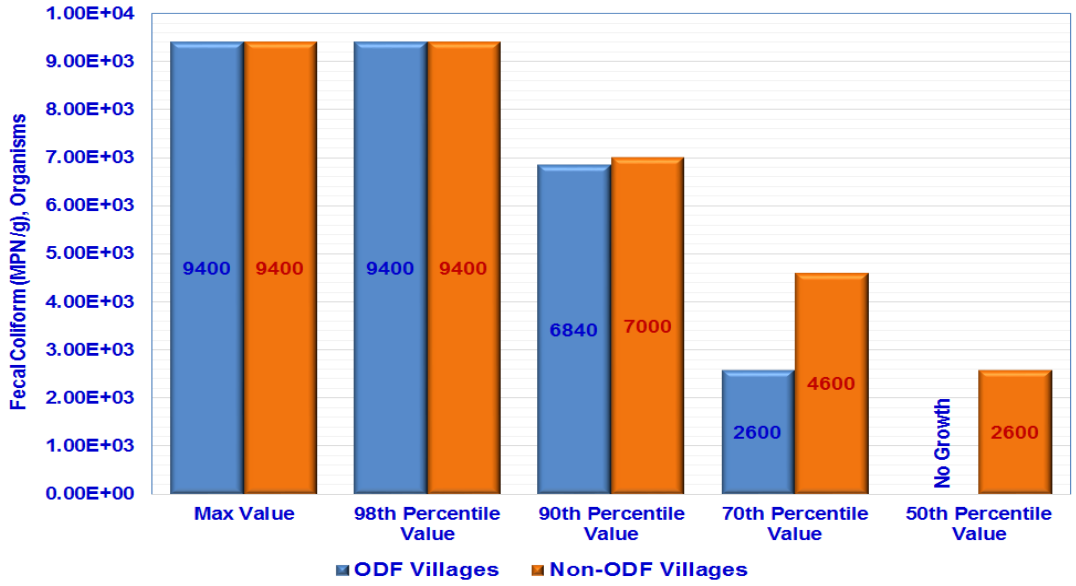
Figure-55 Enterococci (cfu/ 100 ml) in water



(C) Faecal Indicator Bacteria in Soil

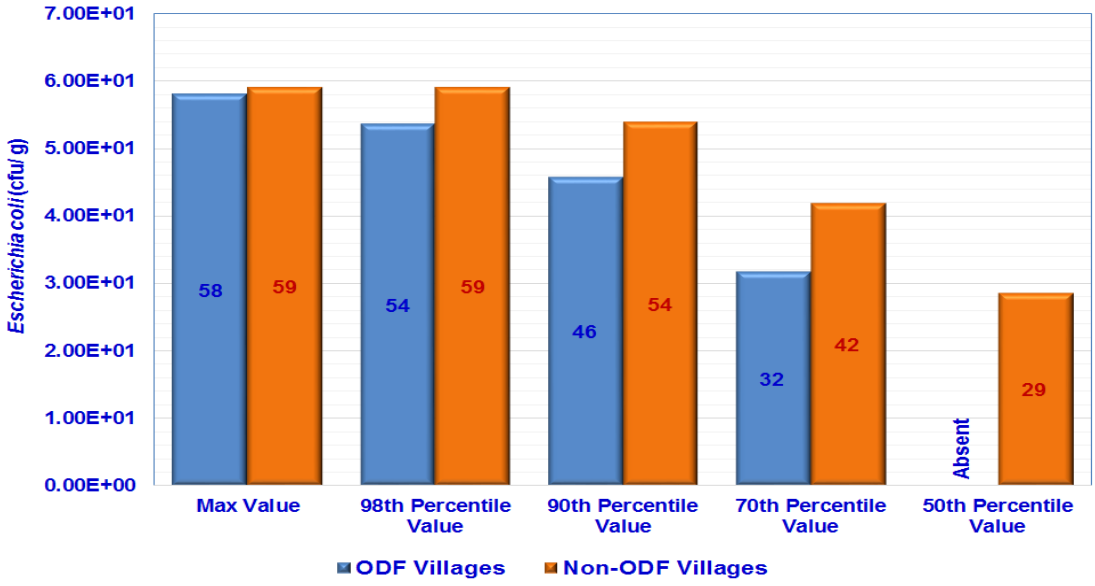
(a) Soil in both ODF and non-ODF villages was found contaminated with faecal coliform with maximum and 98th percentile values 9400 organism (MPN coliform/g). The 50th percentile onward values in ODF showed "No Growth".

Figure-56 Faecal coliform, Organisms (MPN coliform/ g) in soil



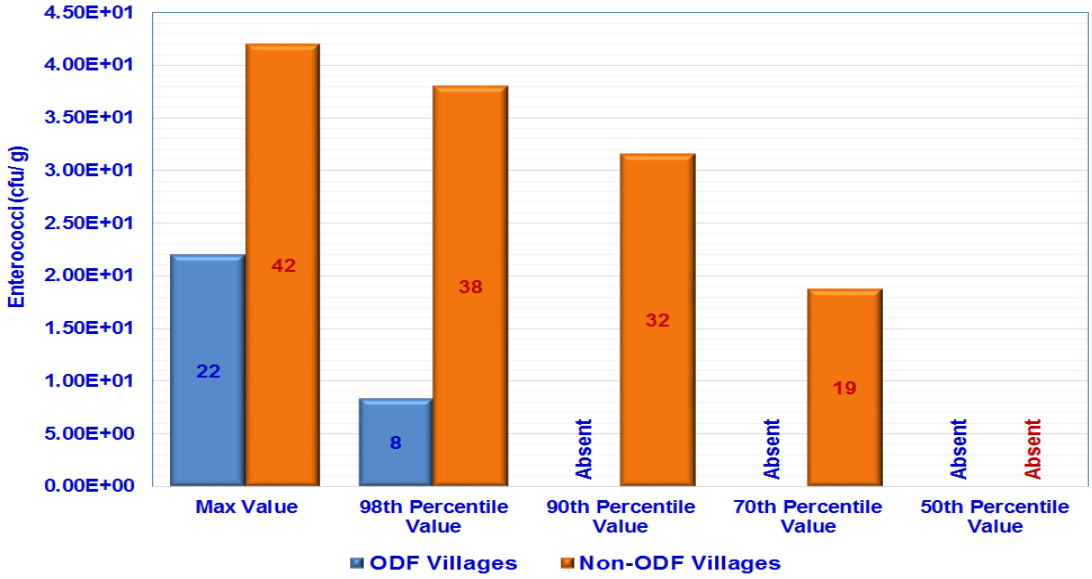
(b) Maximum values of *Escherichia coli*, in soil samples collected from ODF and non-ODF villages, were observed 58 cfu/g and 59 cfu/g respectively. The 50th percentile onward values in ODF villages, were found "Absent".

Figure-57 *Escherichia coli* (cfu/ g) in soil



(c) Maximum values of *Enterococci*, in soil samples collected from ODF and non-ODF villages, were observed 22 cfu/g and 42 cfu/g respectively. The 90th percentile onward values both in ODF, were observed "Absent".

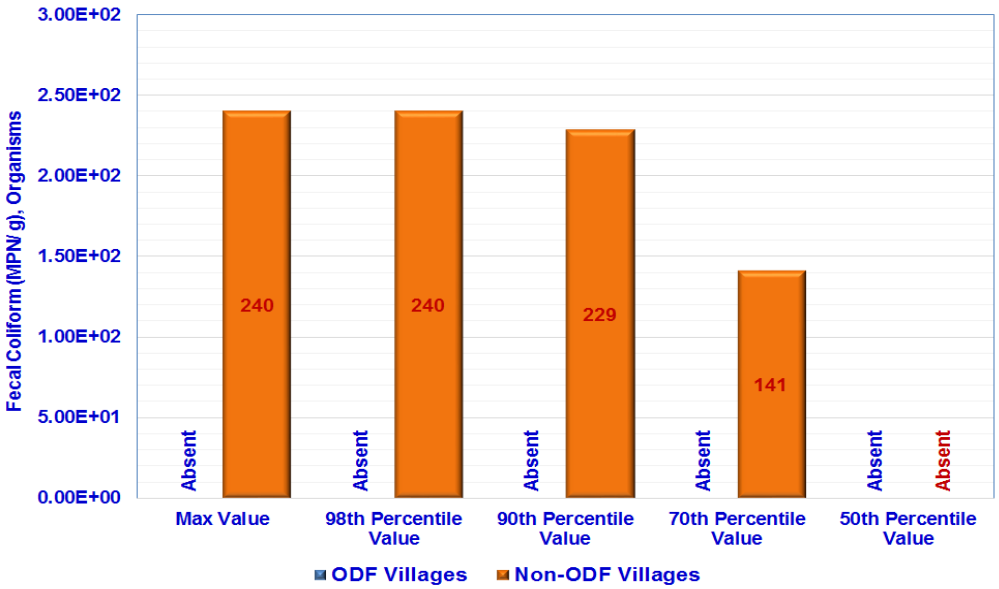
Figure-58 *Enterococci* (cfu/ g) in soil



(D) Faecal Indicator Bacteria in Food

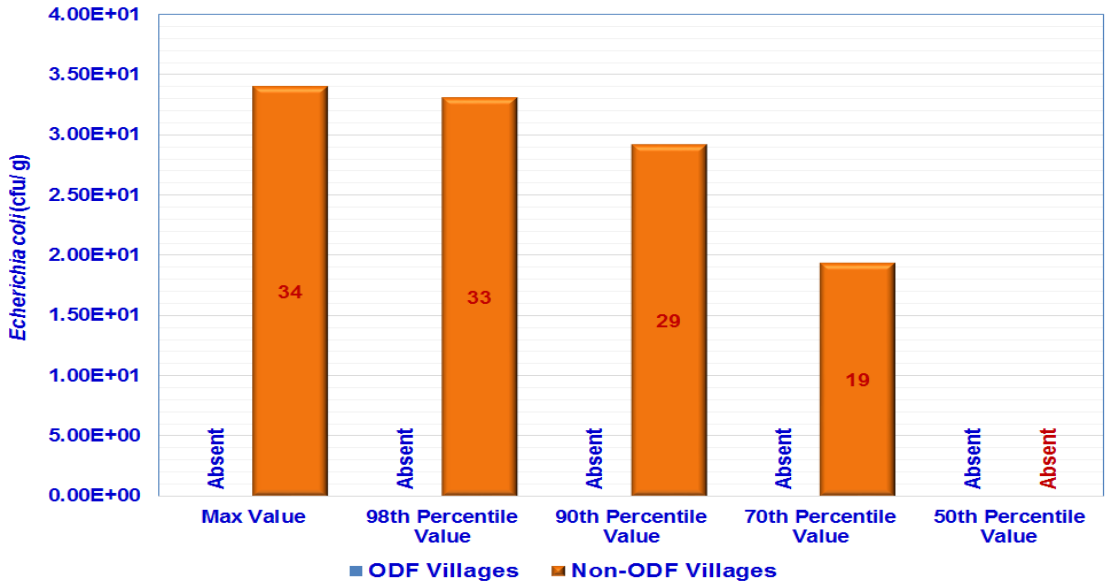
(a) No Growth Observed with respect to Faecal coliform, Organisms (MPN coliform/g) in case of food samples taken from ODF villages.

Figure-59 Faecal coliform, Organisms (MPN coliform/ g) in food



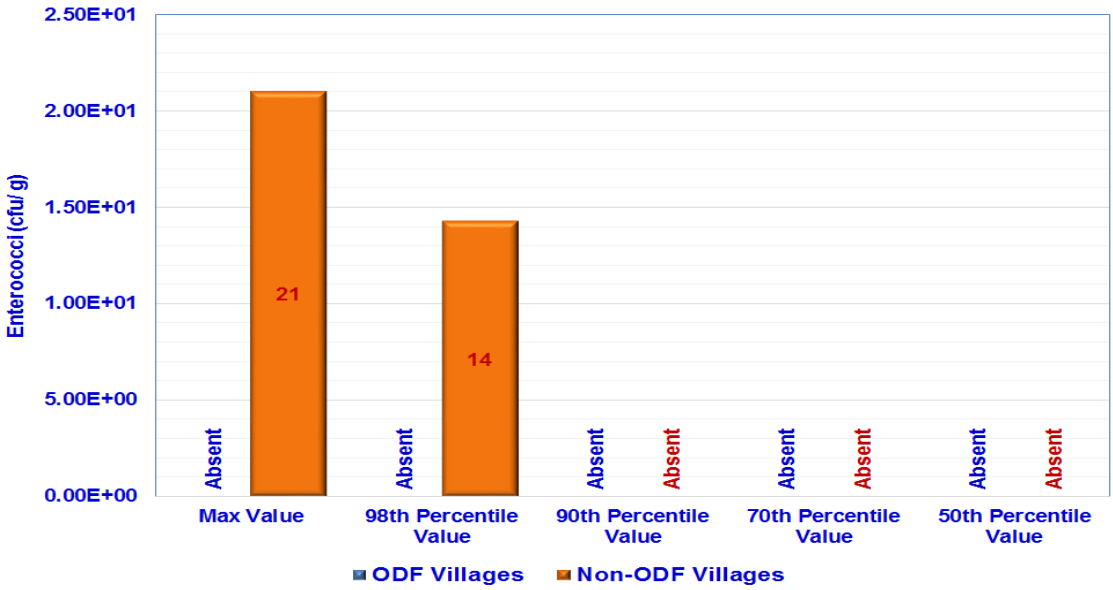
(b) *Escherichia coli*, in food samples taken from ODF villages were found "Absent".

Figure-60 *Escherichia coli* (cfu/ g) in food



(c) Enterococci, in case of food samples taken both from ODF villages was found "Absent", whereas in case of food samples taken from non-ODF villages, the 90th percentile values of Enterococci are "Absent".

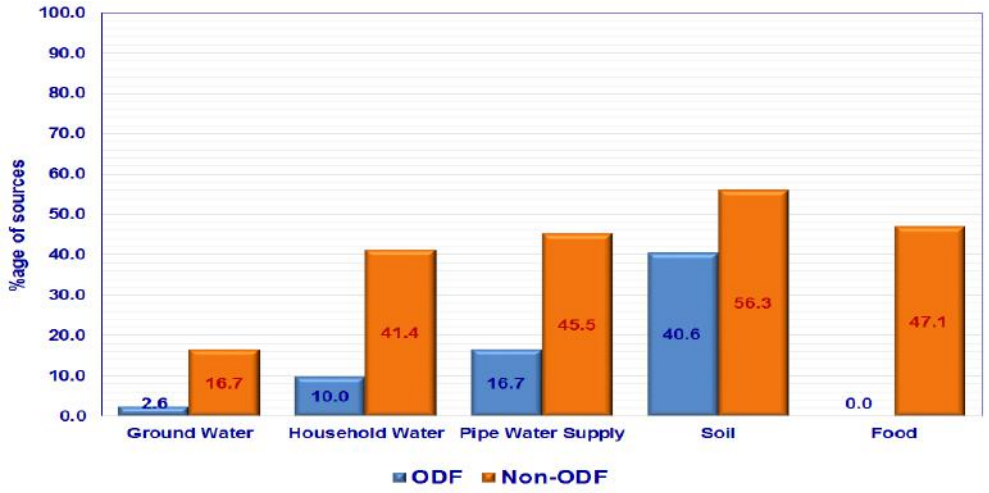
Figure-61 Enterococci (cfu/ g) in food



(E) Risk of ODF and non-ODF villages due to Faecal Contamination of Human Origin

The risk of faecal contamination due to human origin (HuBac) in non-ODF villages in comparison to ODF villages was found to be, 6.50 times more likely in case of groundwater; 0.45 times more likely in case of surface water; 4.14 times more likely in case of household storage water; 2.73 times more likely in case of piped water supply; 1.39 times more likely in case of soil; and 8.47 times more likely in case of food.

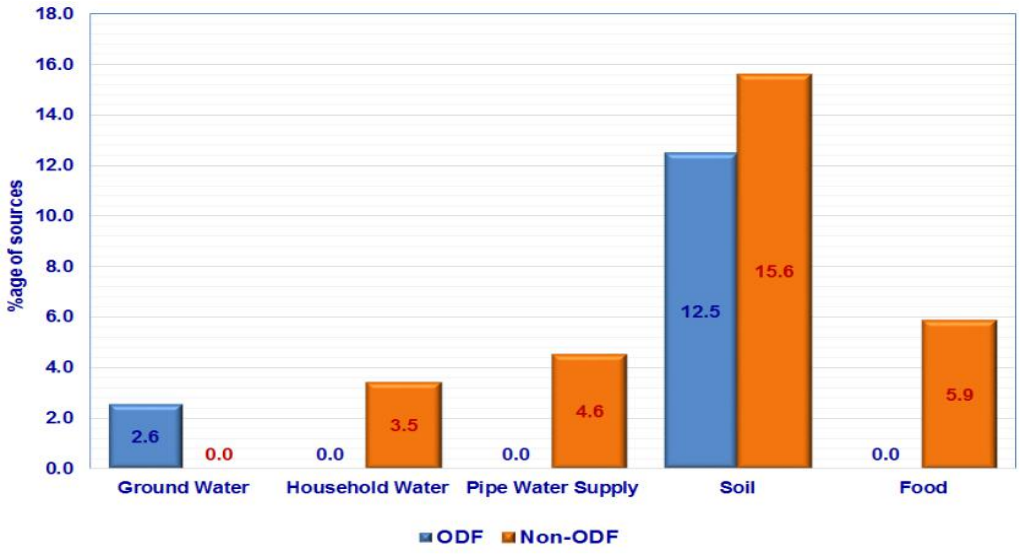
Figure-62 Faecal contamination due to Human Origin



(F) Risk of ODF and non-ODF villages due to Faecal Contamination of Animal Origin

The risk of faecal contamination due to animal origin (RuBac) in non-ODF villages in comparison to ODF villages was found to be, 3.25 times more likely in case of groundwater; 0.09 times more likely in case of surface water; 1.38 times more likely in case of household storage water; 0.55 times more likely in case of piped water supply; 1.25 times more likely in case of soil; and 1.06 times more likely in case of food.

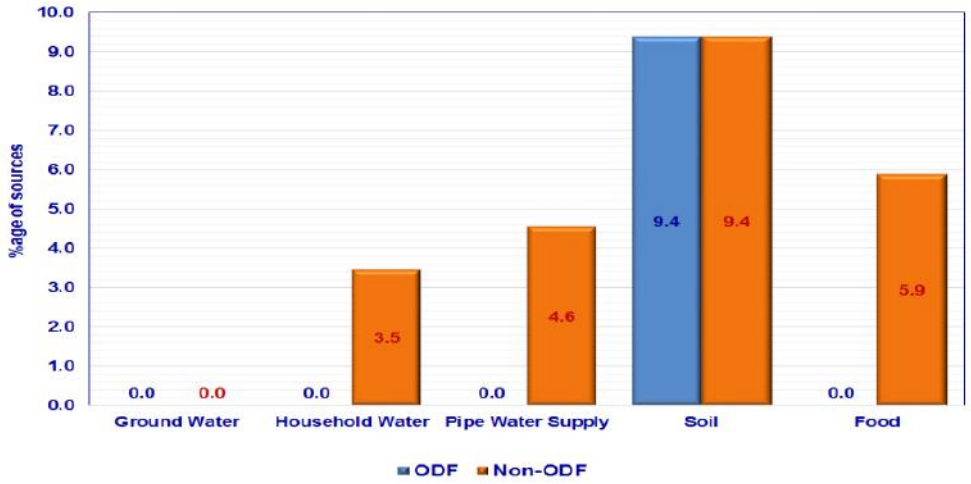
Figure-63 Faecal contamination due to Animal Origin



(G) Risk of ODF and non-ODF villages due to Faecal Contamination of both Human and Animal Origin

The risk of faecal contamination both due to human origin (HuBac) and animal origin (RuBac) in non-ODF villages in comparison to ODF villages was found to be, 6.50 times more likely in case of groundwater; 0.09 times more likely in case of surface water; 1.38 times more likely in case of household storage water; 0.55 times more likely in case of piped water supply; equal in case of soil; and 1.06 times more likely in case of food.

Figure-64 Faecal contamination both due to Human and Animal Origin



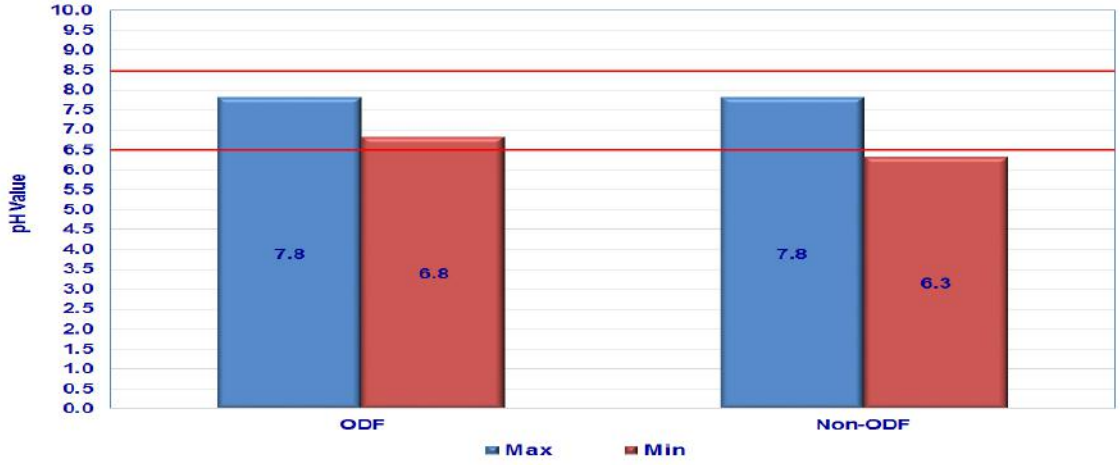
(H) Physico-chemical Properties of Water Sources in ODF and non-ODF villages

(Acceptable and maximum permissible, wherever available, are shown by red lines on the graph)

(a) pH value of water

pH value was found ranging between 6.8 to 7.8 in water samples from ODF villages and 6.3 to 7.8 in water samples from non-ODF villages, which indicates normal pH level except two sources of non-ODF, where it was marginally low i.e 6.3 and 6.4 .

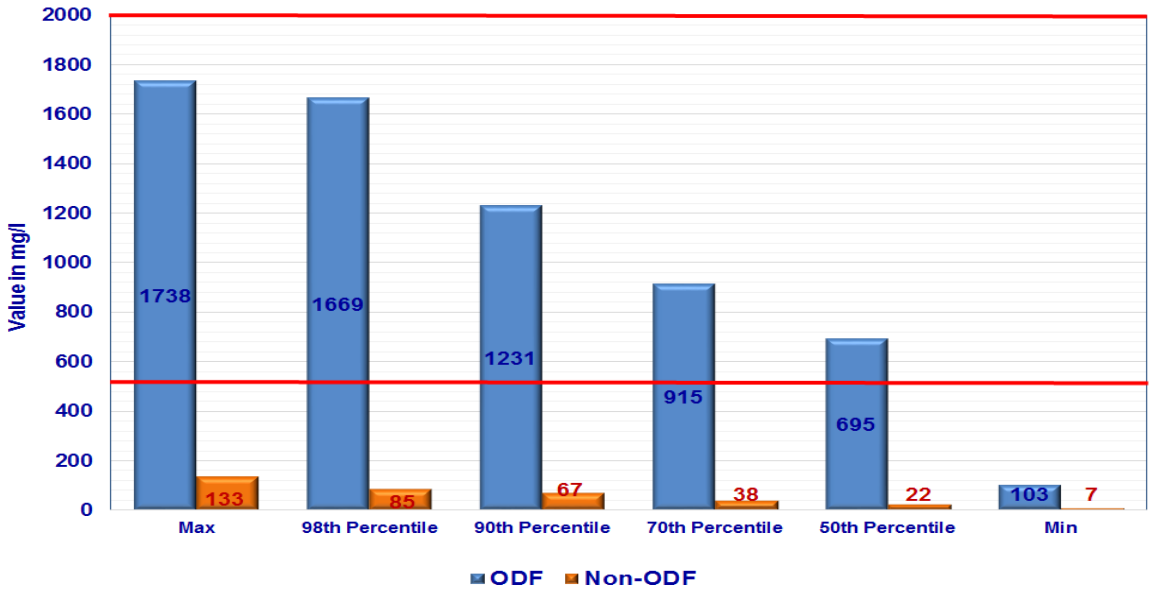
Figure-65 pH value of Water



(b) Total Dissolved Solids (TDS) in water

TDS was found ranging between 103 to 1738 mg/l in ODF villages and 7 to 133 mg/l in non-ODF villages. 100% samples were found within the permissible limit of TDS in water.

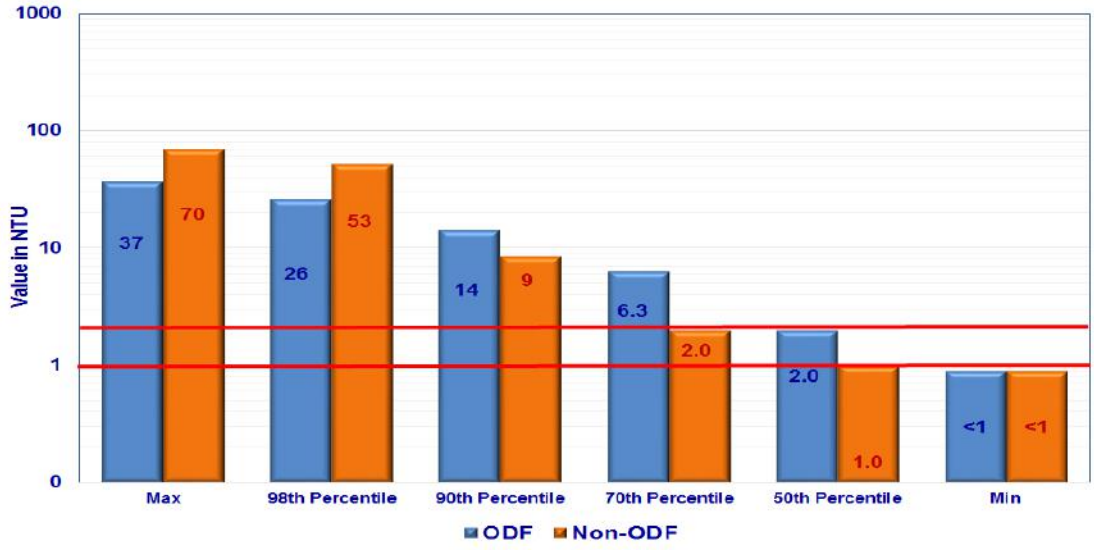
Figure-66 Total Dissolved Solids (TDS) in Water



(c) Turbidity in water

Turbidity was found ranging between <1 to 37 NTU in water samples of ODF villages and between <1 to 70 NTU in water samples of non-ODF villages. 50th percentile onwards values of turbidity in water of both ODF and non-ODF villages, was observed within the permissible limits.

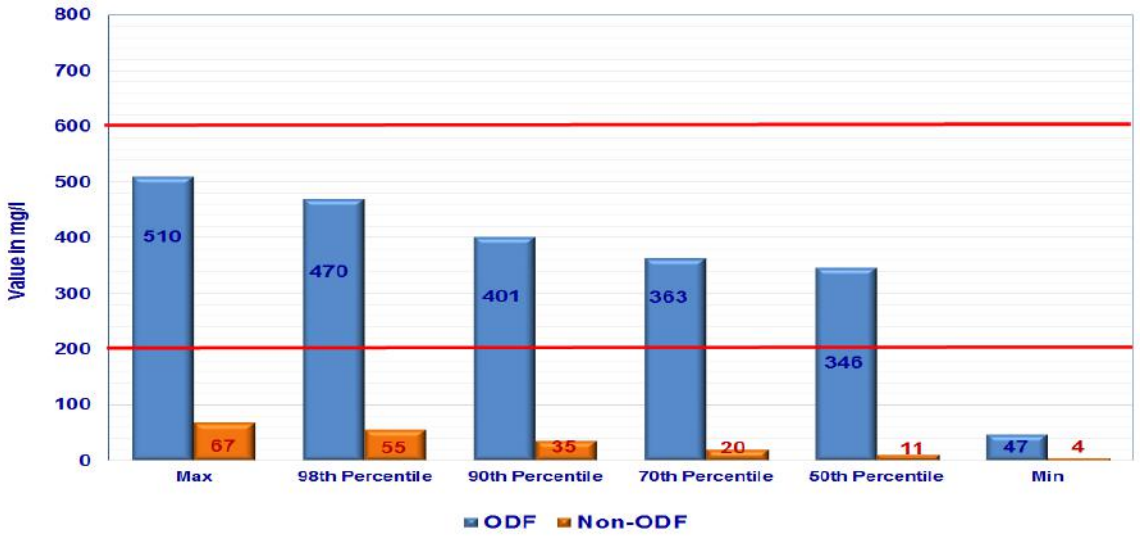
Figure-67 Turbidity in Water



(d) Total Alkalinity in water

Total Alkalinity as $CaCO_3$ was found ranging between 47 to 510 mg/l in ODF villages and 4 to 67 mg/l in non-ODF villages. 100% samples were found within the permissible limit of Total Alkalinity in water.

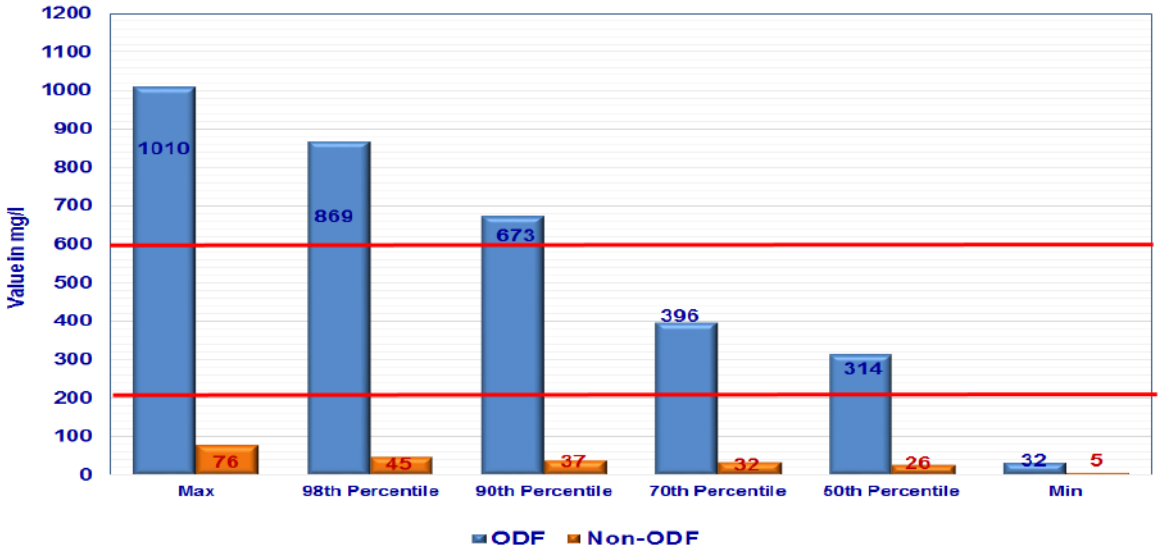
Figure-68 Total Alkalinity in Water



(e) Total Hardness in water

Total Hardness as $CaCO_3$ was found ranging between 32 to 1010 mg/l in ODF villages and 5 to 76 mg/l in non-ODF villages. The 70th percentile onward values of total hardness in ODF villages and 100% values in case of non-ODF villages, were found within the permissible limits of drinking water.

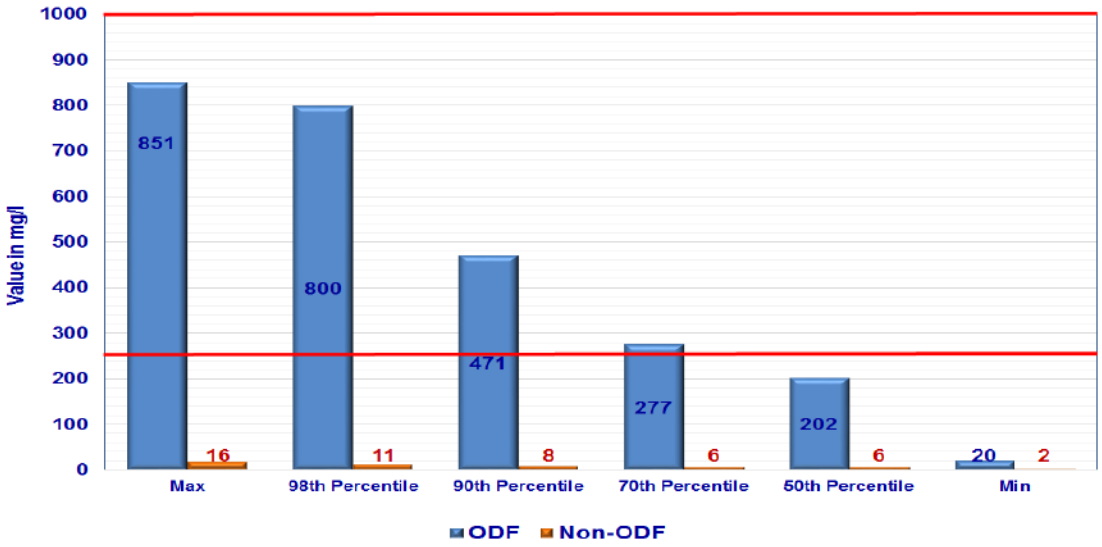
Figure-69 Total Hardness in Water



(f) Chlorides in water

Chloride as Cl was found ranging between 20 to 851 mg/l in ODF villages and 2 to 16 mg/l in non-ODF villages. 100% samples were found within the permissible limit of Chlorides in water.

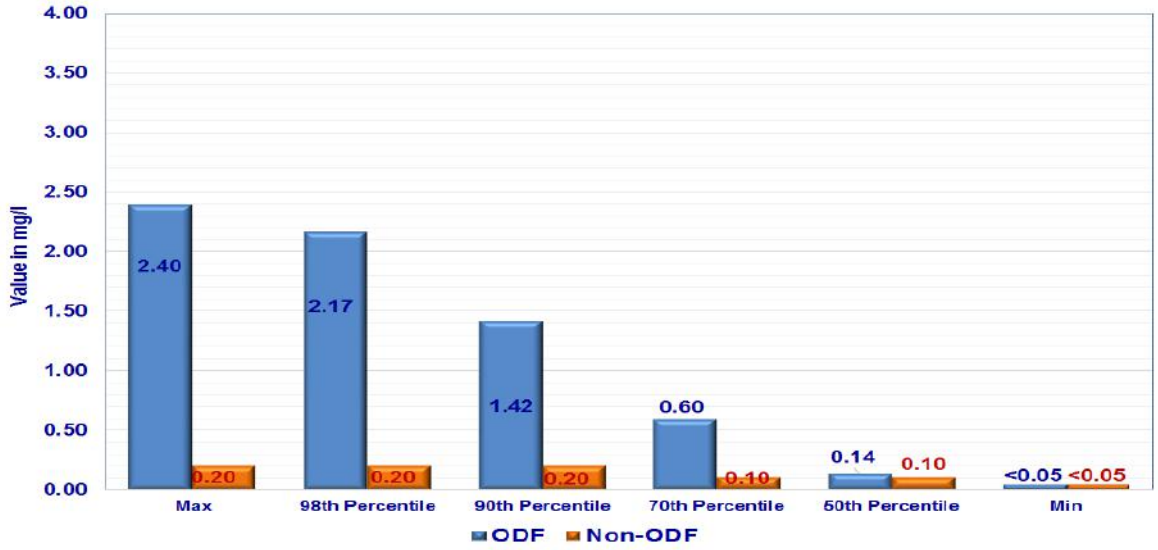
Figure-70 Chlorides in Water



(g) Total phosphorous in water

Phosphorous as P is estimated <0.05 to 2.4 mg/l in ODF villages and <0.05 to 0.2 mg/l in non-ODF villages. The 70th percentile onward values of phosphorous are found below 1.0 mg/l.

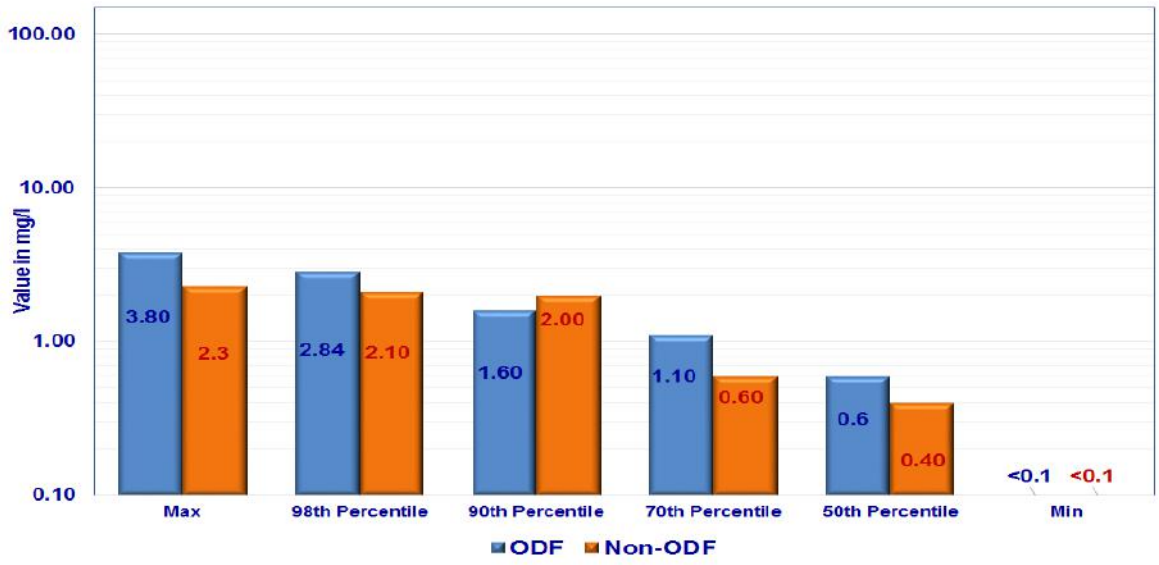
Figure-71 Total phosphorous in water



(h) Total Kjeldahl Nitrogen in water

Total Nitrogen as N were found ranging between 0.10 to 3.8 mg/l in ODF villages and 0.10 to 2.3 mg/l in non-ODF villages. The 70th percentile onward values of nitrogen were found below 1.0 mg/l.

Figure-72 Total Nitrogen in water



(i) Arsenic in water

Arsenic as As is “Not Detected” (Detection Limit 0.01 mg/l) in any of the sample drawn from ODF and non-ODF villages.

Table-17 Summary of Findings: ODF Villages in West Bengal

District			Haora (ODF)			
Block			Bally-Jagacha	Domjur		Panchla
Village			Bally (CT)	Oadipur	Domjur (CT)	Gondalpara
Is Declared ODF			Yes	Yes	Yes	Yes
HH with toilets (% coverage)			100	100	100	100
Environmental Medium			**%age of sampled sources found contaminated**			
Water	Ground Water	FIB	0 %	7.7%	0%	0%
		RuBac	-	7.7%	-	-
		HuBac	-	7.7%	-	-
	Surface Water	FIB	83.3%	66.7%	100%	100%
		RuBac	83.3%	0%	40.0%	0%
		HuBac	83.3%	66.7%	100%	100%
	HH Storage Water	FIB	20.0 %	33.3%	0%	0%
		RuBac	0%	0%	-	-
		HuBac	0%	33.3%	-	-
	Pipe Water Supply	FIB	0%	Sample NA	50.0%	0%
		RuBac	-	-	0%	-
		HuBac	-	-	50.0%	-
Soil		FIB	37.5%	62.5%	62.5%	25.0%
		RuBac	0%	37.5%	12.5%	0%
		HuBac	37.5%	37.5%	62.5%	25.0%
Food		FIB	Sample NA	0%	0%	0%
		RuBac	-	-	-	-
		HuBac	-	-	-	-
Physico-chemical Properties of Water	pH		6.8 to 7.8	7.4 to 7.8	7.4 to 7.6	6.8 to 7.6
	EC, µmhos/cm		164 to 2946	770 to 1988	432 to 1234	1191 to 1690
	TDS, mg/l		103 to 1738	462 to 1233	270 to 770	726 to 1048
	Turbidity, NTU		1 to 37	1 to 26	1 to 25	1 to 20
	Chloride (Cl), mg/l		20 to 851	59 to 475	23 to 217	206 to 337
	Nitrogen (TKN), mg/l		0.1 to 1.4	0.20 to 1.7	1.1 to 3.8	0.1 to 3.2
	Phosphorous (P), mg/l		0.10 to 0.20	0.10 to 2.0	0.30 to 2.4	0.1 to 1.6
	Hardness ($CaCO_3$), mg/l		32 to 1010	216 to 843	105 to 285	214 to 539
	Alkalinity ($CaCO_3$), mg/l		47 to 510	131 to 380	150 to 402	300 to 471
	Arsenic (As), mg/l		<0.01	<0.01	<0.01	<0.01

Table-18 Summary of Findings: non-ODF Villages in West Bengal

District			Darjeeling (Non-ODF)			
Block			Gorubathan		Jore Bunglow Sukhiapokhri	Mirik
Village			Today tangta Khasmahal	Paten Godak Khasmahal	Mariabong Tea Garden	Chota Chenga Belagachi
Is Declared ODF			No	No	No	No
Environmental Medium			**%age of sampled sources found contaminated**			
Water	Ground Water	FIB	Sample NA	Sample NA	Sample NA	0%
		RuBac	-	-	-	-
		HuBac	-	-	-	-
	Surface Water	FIB	80.0	50.0%	50.0	Sample NA
		RuBac	0%	0%	0%	-
		HuBac	40.0%	33.3%	50.0%	-
	HH Storage Water	FIB	55.6	42.9%	60.0%	62.5%
		RuBac	0%	14.3%	0%	0%
		HuBac	44.4%	14.3%	60.0%	50.0%
	Pipe Water Supply	FIB	100%	75.0%	40.0%	66.7%
		RuBac	0%	0%	0%	33.3%
		HuBac	40.0%	75.0%	30.0%	66.7%
Soil		FIB	62.5%	62.5%	75.0%	62.5%
		RuBac	0%	25.0%	0%	37.5%
		HuBac	62.5%	25.0%	75.0%	62.5%
Food		FIB	50.0%	60.0%	0%	60.0%
		RuBac	0%	0%	-	20.0%
		HuBac	50.0%	60.0%	-	60.0%
Physico-chemical Properties of Water	pH		7.3 to 7.8	7.3 to 7.8	6.3 to 6.9	6.5 to 6.9
	EC, µmhos/cm		15 to 64	15 to 64	10 to 204	67 to 139
	TDS, mg/l		9 to 40	9 to 40	7 to 133	42 to 86
	Turbidity, NTU		4 to 5	4 to 12	1 to 2	1 to 70
	Chloride (Cl), mg/l		4 to 11	4 to 11	4 to 16	2 to 6
	Nitrogen (TKN), mg/l		1.5 to 2.3	0.40 to 2.3	0.20 to 0.80	0.20 to 0.40
	Phosphorous (P), mg/l		<0.05 to 0.20	<0.05 to 0.20	<0.05 to 0.20	0.05 to 0.20
	Hardness ($CaCO_3$), mg/l		5 to 35	5 to 35	23 to 76	24 to 42
	Alkalinity ($CaCO_3$), mg/l		6 to 27	6 to 27	4 to 22	20 to 67
	Arsenic (As), mg/l		<0.01	<0.01	<0.01	<0.01

6. Inferences and Conclusions

6.1 Contamination of Water Medium

(A) Key findings of Contamination by Faecal Indicator Bacteria (FIB)

(a) Groundwater:

The relative risk of faecal contamination of groundwater was **11.25 times more likely in non-ODF villages as compared to ODF villages** (53.6 times more in Bihar; 6.50 times more in West Bengal and 3.54 times more in Odisha).

(b) Surface Waters:

The relative risk of faecal contamination of surface water was **0.92 times more likely in non-ODF villages as compared to ODF villages** (1.35 times more in Bihar; 0.68 times more in West Bengal and No Risk in Odisha).

(c) Household Storage Water:

The relative risk of faecal contamination of HH storage water was **2.68 times more likely in non-ODF villages as compared to ODF villages** (3.47 times more in Bihar; 4.37 times more in West Bengal and 1.73 times more in Odisha).

(d) Piped Water Supply:

The relative risk of faecal contamination of PWS was **2.71 times more likely in non-ODF villages as compared to ODF villages** (5.33 times more in Bihar; 3.82 times more in West Bengal and 0.75 times more in Odisha).

(B) Key findings of Faecal contamination from human origin (HuBac)

(a) Groundwater :

The relative risk of faecal contamination of groundwater traceable to humans was **12.7 times more likely in non-ODF villages as compared to ODF villages** (35.7 times more in Bihar; 6.5 times more in West Bengal and 5.3 times more in Odisha).

(b) Surface Water :

The relative risk of faecal contamination of surface water traceable to humans was **0.83 times more likely in non-ODF villages as compared to ODF villages** (1.48 times more in Bihar; 0.45 times more in West Bengal and equal in Odisha).

(c) Household Storage Water :

The relative risk of faecal contamination of HH storage water traceable to humans was **2.48 times more likely in non-ODF villages as compared to ODF villages** (2.74 times more in Bihar; 4.14 times more in West Bengal and 1.44 times more in Odisha).

(d) Piped Water Supply :

The relative risk of faecal contamination of PWS traceable to humans was **2.40 times more likely in non-ODF villages as compared to ODF villages** (1.33 times more in Bihar; 2.73 times more in West Bengal and 1.50 times more in Odisha).

Interpretation/ Analysis

Study findings indicates

- Substantial risk reduction of faecal contamination of human origin in water sources, though magnitude of impact varies;
- Sudden onset of rain during sampling days at Odisha resulted in decreased impact thereby indicating that drainage needs to be improved;
- Low risk reduction in case of surface waters indicates the need for water sources protection;
- Significant improvement observed in case of piped water supply
- Very interesting results on household water translating the results of behavior change component of the SBM improving safe/ hygienic water handling and storage.

6.2 Contamination of Soil Medium

(A) Key findings of Contamination by Faecal Indicator Bacteria (FIB)

The relative risk of faecal contamination of soil was **1.13 times more likely in non-ODF villages as compared to ODF villages** (1.21 times more in Bihar; 1.40 times more in West Bengal and 0.93 times more in Odisha).

(B) Key findings of Faecal contamination from human origin (HuBac)

The relative risk of faecal contamination of soil traceable to humans was **1.10 times more likely in non-ODF villages as compared to ODF villages** (1.21 times more in Bihar; 1.39 times more in West Bengal and 0.89 times more in Odisha).

Interpretation/ Analysis

Study findings indicates

- Low risk reduction due to faecal contamination of human origin in soil of ODF villages;
- The importance of fecal sludge management together with solid and liquid waste management in more effective ways.

6.3 Contamination of Food Medium

(A) Key findings of Contamination by Faecal Indicator Bacteria (FIB)

The relative risk of faecal contamination of food was **1.48 times more likely in non-ODF villages as compared to ODF villages** (6.67 times more in Bihar; 8.47 times more in West Bengal and 0.90 times more in Odisha).

(B) Key findings of Faecal contamination from human origin (HuBac)

The relative risk of faecal contamination of food traceable to humans was **2.16 times more likely in non-ODF villages as compared to ODF villages** (6.67 times more in Bihar; 8.47 times more in West Bengal and 1.14 times more in Odisha).

Interpretation/ Analysis

Study findings indicates

- Significant risk reduction due to faecal contamination of human origin in food of ODF villages, which may be attributed to substantial improvement in terms of hygiene practices and probably monitoring systems to ensure safe practices in terms of food preparation and storage.
- Also very important results indicating potentially great health impact linked to the reduction of diarrhea and stunting.