Microorganisms Associated with Corrosion of Water Pipelines in Minna, Niger State

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ABSTRACT

Microorganisms associated with corrosion of water pipelines in Barkin-Sale, Bosso, Chanchaga, Keteren-Gwari, Maikunkele and Kwangila areas of Minna metropolis in Niger State of Nigeria were isolated. Corroded water pipes and soil samples were analysed for microbiological and physicochemical properties between the months of February and July, 2008. Bacteria isolated were Desulfovibrio desulfuricans, Desulfotomaculum nigrificans, Thiobacillus thiooxidans, Lactobacillus lactis, Clostridium perfringens, Pseudomonas aeruginosa, and Bacillus cereus var mycoides, B. subtilis, B. cereus and Staphylococcus aureus while fungi isolated were Aspergillus niger, A. fumigatus, Penicillium notatum, Candida tropicalis, Mucor mucedo, Torulopsis candida, Geotrichum candidum and Fusarium solani The bacterium most frequently isolated was D. desulfuricans (56.67%) while the fungus with the highest occurrence was A. niger (25.00%). The mean total aerobic bacterial counts ranged from $3.50x10^5$ cfu/g to $7.16x10^4$ cfu/g, mean total anaerobic bacterial counts ranged from $5.59x10^4$ cfu/g to $7.69x10^5$ cfu/g and the mean total fungal count ranged from $3.0x10^3$ cfu/g to $5.63x10^5$ cfu/g. From the data, there were significant differences ($p<0.05$) between the mean total aerobic bacterial counts, anaerobic bacterial counts and fungal counts in the various locations.

Key Words: Microorganisms, water pipes, corrosion, soil samples, microbiological and physicochemical properties
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INTRODUCTION

Corrosion is the deterioration of metal and non metal as a results of its physicochemical interaction with its environment. Microbial influenced corrosion refers to the possibility that microorganisms are involved in the deterioration of metallic as well as non-metallic materials. Microbial influenced corrosion is not a new corrosion mechanism but it integrates the role of microorganism in the corrosion processes (Beech and Flemming, 2000). The primary concern is that the influence of these microbes is often an extremely accelerated rate of corrosion (Akpabio *et. al.*, 2011). Bacterial biofilms are the initiating and/or propagating agents of microbial influenced corrosion. Formation of biofilm creates a microenvironment that is dramatically different from the bulk surrounding (Akpabio *et. al.*, 2011). Microbiological influenced corrosion organisms fall under two groups based on the type of corrosion they engender (i) anaerobic corrosion and (ii) aerobic corrosion (Huggins, 2010). A thorough knowledge of the microorganisms implicated in microbial influenced corrosion is needed so as to increase our understanding of their composition and activities in water pipelines for an improved detection, monitoring and control. Therefore the objectives of this research work are to enumerate, isolate and identify the microorganisms found in biofilms attached to corroded water pipelines surfaces in Minna..

MATERIALS AND METHODS

Study Area

The study area for this research work was Barkin-Sale, Bosso, Chanchaga, Maikunkele, Keteren-Gwari and Kwangila areas of Minna metropolis (Latitude 09 39N, longitude 06 32E). Minna is the capital city of Niger State of Nigeria (longitude 8^0 20'N and 11^0 20'N and 11^0 30'N and longitude 3^0 30'E and 7^0 20'E).

Physical Examination of Water Pipelines

The types of water pipelines affected by corrosion was surveyed and observed. The environments where the pipes were laid were identified as whether they were waterlogged, dried or damp. The physical appearance associated with corrosion was also noted, as described by Geiger *et al.* (1993).

Media and Sterilization

The media used were nutrient agar (Biotech) and sabouraud dextrose agar (Biotech). The selective media used were Postage medium (K_2HP0_4 (0.2g), MgS04. $7H_20$ (0.2g), $(NH_4)_2S0_4$ ·(1.0g), Na_2S0_3(0.1g) $Fe(S0_4)_3(NH_4)_2S0_4.24H_20$

(0.1g), Ascorbic acid (0.1g), Peptone (1g), Yeast extract (1.0g), Carbon lactate (3.5ml), Agar (20g), Water(1000ml) pH:7.0) (Postage, 1966), iron oxidizing medium (NH_4Cl (0.1g), KH_2PO_4 (3.0g), $MgCl_2.2H_20$ (0.14g), S (10g), Agar (20g), Water (1000ml), pH: 4.2) (Starkey,1935) and Starkey broth (KH_2PO_4 (3.0g), $MgSO_4.7H_20$ (0.2g), $CaCl_2$. $2H_20$ (0.2g), $(NH_4)_2SO_4$ (0.5g), $FeSO_4$ (0.001g), Water (1000ml), pH:8.0) (Starkey, 1935). The media were sterilized using autoclave at 121^{O}C for 15 minutes.

Experimental Design and Sample Collection

The one-short case study was used as described by Cook and Campbell (1979). Each corroded water pipe surfaces in Barkin-Sale, Bosso, Chanchaga, Keteren-Gwari, Maikunkele and Kwangila areas of Minna were identified between the months of February and July. Sterile lancets were used to obtain surface scrapings from a 1cm^2 area of each identified corroded water pipe. Ten samples were collected from each of these locations. The samples were collected in sterile MacCartney bottles, labelled and taken to the microbiology laboratory of Federal University of Technology, Minna for microbial analysis.

A total of sixty surface scrapings were obtained for microbial analysis (aerobic and anaerobic).

Enumeration, Isolation and Identification of Bacteria

One gram (1g) of surface scraping samples of each corroded water pipelines obtained from Barkin-Sale, Bosso, Chanchaga, Keteren-Gwari, Maikunkele and Kwangila, was serially diluted ten folds with 9ml of sterile, distilled water and aseptically plated on nutrient agar and the selective media. One milliliter (1ml) of diluents was inoculated into sterile Petri dish containing a solidified medium. Sterile bent rod (Hockey stick) was aseptically used to spread the diluents on the surface of the media.

The inoculated nutrient agar, Starkey broth and iron oxidizing bacteria medium were incubated at 37^{O}C for 24 – 48 hours while the inoculated Postgate medium was incubated in an anaerobic jar containing alkaline pyrogalol at 37^{0}C for 24 – 48hours. A duplicate of the inoculated nutrient agar plate was also incubated anaerobically at 37^{0}C for 24 – 48hours.

After incubation, the bacterial colonies which developed from the nutrient agar plates were enumerated using a colony counter (Model 6399 by Stuart Scientific Co. Ltd., Great Britain) and their count, expressed as colony forming units per gram (cfu/g) of samples. Bacterial colonies differing in size, shape and colour were selected from the different plates and further sub cultured on nutrient agar by the streak plate technique and incubated at 37^{0}C for 24 hours after which they were maintained on agar slants for further characterization and identification.

The bacterial isolates were characterized based on colonial morphology, cultural characteristics and biochemical tests as described by Fawole and Oso (1998) and Oyeleke and Manga (2008). The isolates were identified by comparing their characteristics with those of known taxa using the Bergey's manual of determinative bacteriology (Holts *et. al.*, 1994).

Enumeration, Isolation and Identification of Fungi

One gram (1g) of the surface scrapings of each corroded water pipelines obtained from Barkin-Sale, Bosso, Chanchaga, Keteren-Gwari, Maikunkele and Kwangila areas of Minna, was serially diluted ten folds with sterile, distilled water and was also cultured on sabouraud dextrose agar for the enumeration and identification of fungi.

One milliliter (1ml) of diluents was inoculated into sterile Petri dish containing sabouraud dextrose agar. Bent rod (Hockey stick) was aseptically used to spread the diluents on the surface of the

media. After incubation for 48hours, the fungal colonies which developed from the sabauroud dextrose agar plates were counted using a colony counter (Model 6399 by Stuart Scientific Co. Ltd., Great Britain) and their count, expressed as colony forming units per gram (cfu/g) of samples.

A small portion of the mycelia growth was carefully picked with the aid of a pair of sterile inoculating needles and placed in a drop of lactophenol cotton blue on a microscope slide and covered with a cover slip. The slide was examined under the microscope, first with (x10) and then with (x40) objective lens for morphological examination as described by Fawole and Oso (1998) and Oyeleke and Manga, (2008). The isolates were identified by comparing their characteristics with those of known taxa using the schemes of Domsch and Gams (1970).

Statistical Analysis of Data

The data obtained from this study was subjected to statistical analysis using one way analysis of variance (ANOVA) and Pearson correlation with MINITAB 14 package.

RESULTS

Total Microbial Counts (cfu/g) of Water Pipeline Scrapings from Different Locations

Total aerobic bacterial counts (cfu/g)

The total aerobic bacterial counts of water pipeline scrapings obtained from Barkin-Sale ranged from ND to 1.3 x 10^5 cfu/g, Bosso ranged from ND to 1.0 x 10^4cfu/g, Chanchaga ranged from ND to 2.1 x 10^5cfu/g, Keteren-Gwari ranged from ND to 2.0 x 10^5 cfu/g, Maikunkele ranged from ND to 1.3 x 10^5cfu/g and Kwangila ranged from ND to 7.0 x 10^4 cfu/g (Table 1).

The highest mean total aerobic bacterial count (7.16 x 10^4 cfu/g) was obtained in Chanchaga followed by Maikunkele (3.88 x 10^4 cfu/g). The least was obtained in Bosso (3.50 x 10^3 cfu/g) (Table 1). Statistical analysis of data showed that there were significant differences ($p<0.05$) between the total aerobic bacterial counts from Barkin-Sale, Bosso, Chanchaga, Maikunkele, Keteren-Gwari and Kwangila.

Table 1: Total aerobic bacterial counts (cfu/g) of scrapings from water pipelines

	Locations					
Sample No.	BS	BO	CH	KG	MK	KW
1	ND	$1.0X10^4$	ND	ND	ND	ND
2	$1.0X10^2$	$3.3X10^2$	$5.0X10^3$	$3.1X10^4$	ND	ND
3	$1.0X10^3$	ND	ND	ND	$1.0X10^3$	$4.0X10^4$
4	$1.5X10^2$	ND	ND	$1.5X10^3$	$1.5X10^2$	ND
5	$2.0X10^3$	ND	ND	$1.7x10^2$	$3.0x10^2$	$7.0x10^4$
6	ND	ND	$1.0x10^4$	ND	$1.0x10^5$	ND
7	ND	ND	$2.3x10^3$	ND	ND	ND
8	$1.3x10^5$	ND	$2.0x10^3$	ND	ND	$3.5x10^4$
9	$1.3x10^5$	ND	$2.1x10^5$	$4.5x10^3$	$1.3x10^5$	$5.4x10^4$
10	ND	ND	$2.0x10^5$	$2.0x10^5$	$1.1x10^3$	ND
Mean count	$2.67x10^{4bc}$ ±288.90	$3.5x10^{3c}$ ±39.51	$7.16x10^{4a}$ ±462.69	$3.96x10^{4b}$ ±355.49	$3.88 x10^{4b}$ ±267.48	$2.00x10^{3bc}$ ±117.40

KEY: BS- Barkin-Sale, BO-Bosso, CH-Chanchaga, KG-Keteren-Gwari, MK-Maikunkele. KW-Kwangila, ND-not detected, ± - standard error of the mean. Means carrying the same superscript do not differ significantly from each other ($P>0.05$) means carrying different superscripts differ significantly from each other ($P<0.05$) while means carrying two superscripts do not differ significantly from the two ($P>0.05$).

Total anaerobic bacterial counts (cfu/g)

The total anaerobic bacterial counts of water pipeline scrapings obtained from Barkin-Sale ranged from 1.1 x 10^2 to 3.5 x 10^6 cfu/g, Bosso ranged from 3.3 x 10^3 to 3.7 x10^7 cfu/g, Chanchaga ranged from ND to 3.5 x 10^5 cfu/g, Keteren-Gwari ranged from ND to 7.0 x 10^6 cfu/g, Maikunkele ranged from 1.5 x 10^3 to 3.5x10^6 cfu/g and Kwangila ranged from 1.5x10^5 to 5.0x10^7cfu/g (Table 2).

The highest mean total anaerobic bacterial count (7.70x10^6 cfu/g) was obtained in Kwangila followed by Bosso (7.14x10^6

cfu/g). The least was obtained in Chanchaga ($5.59x10^4$ cfu/g) (Table 2). Statistical analysis of data showed that there were significant differences ($P<0.05$) between the total anaerobic bacterial counts from Barkin-Sale, Bosso, Chanchaga, Maikunkele, Keteren-Gwari and Kwangila.

Table 2: Total anaerobic bacteria counts (cfu/g) of scrapings from water pipelines

Sample No.	Locations BS	BO	CH	KG	MK	KW
1	$3.0x10^5$	$3.5x10^6$	$2.5x10^4$	$1.9x10^2$	$2.5x10^3$	$1.5x10^5$
2	$1.1x10^2$	$3.0x10^5$	$5.0x10^3$	ND	$2.1x10^3$	$5.0x10^5$
3	$1.5x10^3$	$3.7x10^7$	$5.0x10^4$	$1.7x10^4$	$1.5x10^3$	$5.0x10^7$
4	$2.5x10^5$	$3.3x10^3$	$3.5x10^4$	ND	$2.5x10^3$	$2.5x10^6$
5	$1.0x10^3$	$1.7x10^6$	$3.4x10^3$	ND	$1.0x10^5$	$6.0x10^6$
6	$3.5x10^6$	$2.0x10^5$	ND	$1.8x10^3$	$3.5x10^6$	$1.5x10^6$
7	$2.1x10^4$	$2.1x10^5$	ND	$2.8x10^5$	$1.9x10^3$	$3.5x10^6$
8	$2.5x10^5$	$2.5x10^7$	$3.5x10^5$	$7.0x10^6$	$1.7x10^3$	$3.0x10^6$
9	$4.0x10^5$	$3.0x10^6$	$3.0x10^3$	$3.2x10^6$	$4.0x10^3$	$5.0x10^6$
10	$3.5x10^4$	$2.2x10^6$	$1.3x10^2$	ND	$4.8x10^3$	$4.8x10^6$
Mean count	$4.49x10^{5c}$ ±3608.33	$7.14x10^{6a}$ ±43117	$5.59x10^{4d}$ ±454.69	$2.10x10^{6b}$ ±15264.50	$3.62x10^{5c}$ ±3676.60	$7.70x10^{6a}$ ±49962

KEY: BS- Barkin-Sale, BO-Bosso, CH-Chanchaga, KG-Keteren-Gwari, MK-Maikunkele. KW-Kwangila, ND-not detected, ± - standard error of the mean. Means carrying the same superscript do not differ significantly from each other ($P>0.05$) means carrying differ superscripts differ significantly from each other ($P<0.05$) while means carrying two superscripts do not differ significantly from the two ($P>0.05$).

Total fungal counts (cfu/g)

The total fungal counts of water pipeline scrapings obtained from Barkin-Sale ranged from ND to $3.5x10^6$cfu/g, Bosso ranged from ND to $1.2x10^5$cfu/g, Chanchaga ranged from ND to $2.2x10^5$cfu/g, Keteren-Gwari ranged from ND to $3.5x10^3$cfu/g, Maikunkele ranged from ND to $3.5x10^4$cfu/g and Kwangila ranged from ND to $3.5x10^6$cfu/g (Table 3). The highest mean total fungal count ($5.63x10^5$cfu/g) was obtained in Kwangila followed by Barkin-Sale ($1.17x10^5$cfu/g). The least was obtained in Keteren-Gwari ($3.0x10^3$cfu/g) (Table 3). Statistical analysis of data showed from Barkin-Sale, Bosso, Chanchaga, Maikunkele, Keteren-Gwari and Kwangila.

Table 3: Total fungi counts (cfu/g) of scrapings from water pipelines

Sample No.	Locations BS	BO	CH	KG	MK	KW
1	ND	ND	$5.0x10^2$	ND	$1.5x10^3$	$1.5x10^3$
2	$1.0x10^2$	ND	ND	ND	$1.5x10^4$	1.5x104
3	ND	$2.0x10^3$	ND	$3.5x10^3$	ND	ND
4	ND	$5.0x10^2$	ND	$3.5x10^3$	ND	$7.5x10^4$
5	$3.5x10^6$	$2.0x10^4$	$1.5x10^3$	ND	$3.5x10^4$	$3.5x10^6$
6	ND	ND	$2.2x10^5$	ND	ND	$3.0x10^5$
7	ND	ND	ND	ND	$1.0x10^4$	$1.3x10^4$
8	$1.0x10^3$	$1.3x10^4$	ND	$2.0x10^3$	$1.0x10^2$	$2.6x10^2$
9	ND	$1.3x10^3$	ND	ND	ND	ND
10	$1.1x10^3$	$1.2x10^5$	ND	$2.1x10^3$	ND	$6.0x10^5$
Mean count	$1.18x10^{5b}$ ±1010.32	$8.37x10^{4c}$ ±653.12	$7.4x10^{4c}$ ±893.78	$3.0x10^{3c}$ ±6.36	123 $x10^{4d}$ ±70.5	5.63x 10^{5a} ±4555.61

KEY: BS- Barkin-Sale, BO-Bosso, CH-Chanchaga, KG-Keteren-Gwari, MK-Maikunkele. KW-Kwangila, ND-not detected, ± - standard error of the mean. Means carrying the same superscript do not differ significantly from each other ($P>0.05$) means carrying differ superscripts differ significantly from each other ($P<0.05$) while means carrying two superscripts do not differ significantly from the two ($P>0.05$).

Microorganisms Isolated from Different Locations in Minna. Table 4 shows the microorganisms isolated from Barkin-Sale, Bosso, Chanchaga, Maikunkele, Keteren-

Gwari and Kwangila. The bacterial isolates were identified as *Desulfovibrio desulfuricans*, *Desulfotomaculum nigrificans*, *Pseudomonas aeruginosa*, *Clostridium perfringens*, *Lactobacillus lactis*, *Bacillus cereus* var *mycoides*, *B. subtilis*, *B. cereus*, *Thiobacillus thiooxidans* and *Staphylococcus aureus*. The fungi isolates were also identified as *Aspergillus niger*, *A. fumigatus*, *Penicillum notatum*, *Mucor mucedo*, *Torulopsis candida*, *Candida tropicalis*, *Geotrichum candidum*, and *Fusarium solani*.

Table 4:Microorganisms associated with different types of pipeline corrosion in Minna

Location	Description of pipes	Bacteria isolated	Fungi isolated
Barkin-Sale	Brown patches, conjugated roughs Black colouration	*Cl. perfringens*, *B. cereus*, *D.desulfuricans*, *P.aeruginosa*, *Dt. nigrificans*	*A. niger*
Bosso	Coarse face and depression Brown surface with underneath colouration and clusters of pits.	*P. aeruginosa* *T. thiooxidans* *D. desulfuricans* *Dt. nigrificans*	*P. notatum*, *A.niger*, *A. niger*, *M. mucedo*, *T. candida*, *F. solani*. *C. tropicalis*
Chanchaga	Brown patches Hard crust Heavy black colouration	*L. lactis*, *B. cereus* var *mycoides*, *P. aeruginosa*, *T. thiooxidans*, *Dt. nigrificans*, *D. desulfuricans*.	*A. niger*, *M. mucedo*
Maikunkele	Black colouration, Brown patches with hard crust	*D. desulfuricans*. *B. cereus* *Dt. nigrificans*, *B. cereus* var *mycoides*, *P. aeruginosa*	*A. fumigatus*, *A. niger*, *M. mucedo*
Keteren-Gwari	Brown patches, hard crust Black colouration	*Cl. perfringens* *T. thiooxidans*, *P. aeruginosa*, *D. desulfuricans* *L. lactis* *Dt. nigrificans*	*A. niger*, *A. fumigatus*, *F. solani*. *P. notatum* *M. mucedo*
Kwangila	Conjugated roughs, brown patches with underlying heavy black colouration with clusters of pits.	*S. aureus* *D. desulfuricans*, *Dt. nigrificans*, *B. cereus* var *mycoides*	*T. candida* *C. tropicalis*, *M. mucedo*, *G. candidum* *A. niger*

Percentage Frequency of Occurrence of Bacterial Isolates from Different Locations in Minna.

Table 5 shows the percentage frequency of occurrence of bacterial isolates from Barkin-Sale, Bosso, Chanchaga, Maikunkele, Keteren-Gwari and Kwangila out of the 60 samples of corroded water pipeline scrapings collected. *D. desulfuricans* had the highest occurrence of 56.67% followed by *Dt. nigrificans* which had a percentage occurrence of 33.33%. The bacteria with the least frequency of occurrence were *L. lactis* and *S. aureus* both with percentage occurrence of 1.67% (Table 5).

Table 5: Percentage Frequency of Occurrence of Bacteria Isolates

Location / Isolates	BS	BO	CH	MK	KG	KW	Total
Cl. perfringens	1(1.67)	0(0)	1(1.67)	0(0)	1(1.67)	0(0)	3(5.01)
B.cereus var *mycoides*	4(5.00)	0(0)	1(1.67)	1(1.67)	0(0)	3(5.01)	5(8.33)
P. aeruginosa	1(1.67)	1(1.67)	2(3.33)	3(5.01)	1(1.67)	0(0)	8(13.33)
T. thiooxidans	0(0)	1(1.67)	3(5.01)	0(0)	5(8.33)	0(0)	9(15.00)
Dt. nigrificans	5(8.33)	4(6.67)	4(6.67)	5(8.33)	1(1.67)	1(1.67)	20(33.33)
D. desulfuricans	7(7.14)	8(8.16)	4(6.67)	6(10.00)	4(6.67)	5(8.33)	34(56.67)
L. lactis	(0.0)	0(0)	0(0)	0(0)	1(1.67)	0(0)	1(1.67)
B. cereus	1(1.67)	0(0)	0(0)	2(3.33)	0(0)	0(0)	3(5.01)
S. aureus	0(0)	0(0)	0(0)	0(0)	0(0)	1(1.67)	1(1.67)
B. subtilis	0(0)	0(0)	0(0)	0(0.0)	0(0)	3(5.01)	3(5.01)

Numbers in parenthesis represent percentage frequency of occurrence
Key:BS-Barkin-Sale, BO-Bosso, CH-Chanchaga, KG-Keteren-Gwari, MK-Maikunkele, KW-Kwangila

Percentage Frequency of Fungal Isolates from Different Locations in Minna.

Table 6 shows the percentage frequency of occurrence of fungal isolates from Barkin-Sale, Bosso, Chanchaga, Maikunkele, Keteren-Gwari and Kwangila out of the 60 samples of corroded water pipeline scrapings collected. *A. niger* had the highest occurrence of 25.00% followed by *A. fumigatus* and *M. mucedo* each with a percentage occurrence of 8.33%. The fungi with the least occurrence were *P. notatum.* and *G. candidum* both with percent occurrence of 63.33% (Table 6).

Table 6: Percentage Frequency of Occurrence of Fungal Isolates

Location / Isolates	BS	BO	CH	MK	KG	KW	Total
A. niger	4(6.67)	2(3.33)	2(3.33)	4(6.67)	1(1.67)	2(3.33)	15(25.00)
A. fumigatus	0(0)	2(3.33)	0(0)	1(1.67)	2(3.33)	0(0)	5(8.33)
P. notatum	0(0)	1(1.67)	0(0)	0(0)	1(1.67)	0(0)	2(3.33)
M. mucedo	0(0)	1(1.67)	1(1.67)	1(1.67)	1(1.67)	1(1.67)	5(8.33)
F. solani	0(0)	1(1.67)	0(0)	0(0)	1(1.67)	0(0)	2(3.33)
C. tropicalis	0(0)	1(1.67)	0(0)	0(0)	0(0)	2(8.33)	3(5.00)
T. candida	0(0)	1(1.67)	0(0)	0(0)	0(0)	2(8.33)	3(5.00)
G. candidum	0(0)	0(0)	0(0)	0(0)	0(0)	2(3.33)	2(3.33)

Numbers in parenthesis represent percentage frequency of occurrence
Key:BS-Barkin-Sale, BO-Bosso, CH-Chanchaga, KG-Keteren-Gwari, MK-Maikunkele, KW-Kwangila

Discussion

The highest mean total aerobic bacterial count was recorded in Chanchaga while the highest mean total anaerobic bacterial and fungal counts were recorded in Kwangila and Bosso. There were significant differences ($P<0.05$) in the mean total aerobic counts, mean total anaerobic counts and the mean total fungal counts in all the locations.

The sulphate reducing bacteria (SRB) isolated were *D. desulfuricans* and *Dt. nigrificans*. SRB are usually not the first group of organisms to become established in pipeline water systems (Barton, 1997). According to the report, initially, microbial populations are composed predominantly of aerobic microorganisms. As these grow, biofilms accumulate and a strong reducing environment develops at the point of attachment. The SRB now begin to grow. The metabolites of the aerobic microorganisms not only produce reducing conditions but also provide nutrients for the SRB, which permit them to grow at a rapid rate. Corrosion develops in the areas where the SRB have grown to high numbers (Barton, 1997). *Thiobacillus thiooxidans*, *P. aeruginosa, B. cereus* var *mycoides, B. subtilis*, *B. cereus, S. aureus, L. lactis* and *Cl. perfringens* were also isolated. According to Videla, 2001, they colonize the metal surface, thereby creating oxygen free environment for anaerobic bacteria, especially sulphate reducing bacteria. Isolation of these organisms further buttress evidence to the hypothesis that acid producing bacteria also play a role in microbial influenced corrosion.

Aspergillus niger, A. fumigatus, P. notatum, M. mucedo, C. tropicalis, T. candida, G. candidium and *F. solani* were

the fungi isolated. These organisms contribute to biocorrosion probably by the production of organic acids which corrode the metals. *C. tropicalis* and *T. candida.* may also contribute to corrosion by the production of slime which can provide an excellent condition required for the proliferation of the SRB. The bacterium with the highest percentage frequency of occurrence was *D. desulfuricans* with frequency of 56.67% followed by *Dt. nigrificans* which had a percentage occurrence of 33.33%. The bacteria with the least occurrence were *L. lactis* and *S. aureus* both with frequency of 1.67%. The high occurrence of *D. desulfuricans* and *Dt. nigrificans* may be due to their ability to better utilize the water pipes for their growth and metabolism than the other bacteria. This implies that *D. desulfuricans* and *Dt. nigrificans* were the most significant bacteria in the corrosion of water pipelines in Minna.

The fungus with the highest occurrence was *A. niger* with frequency of isolation of 25.00% followed by *A. fumigatus* and *M. mucedo* each with a percentage occurrence of 8.33%. The fungi with the least occurrence were *P. notatum* and *G. candidum* both with frequency of isolation 3.33%. Hence *A. niger* was the most important fungus found in surface scrapings of corroded water pipes in Minna. This may be due to its ability to produce wide range of organic and inorganic acids capable of corroding the water pipes while it derives the materials necessary for its growth and metabolism from the corroding pipes.

The isolation of these microorganisms in water pipes in different locations in Minna, Niger State suggests their contributions in the corrosion of the water pipes. Corroded pipes may eventually perforate, resulting into the influx of pathogenic microorganisms, particles and heavy metals that may cause several health implications to the populace. There is therefore need for urgent attention to the monitoring and replacement of corroded water pipelines in Minna to safeguard the health of the general public and ensure safe water supplies.

REFERENCES

Akpabio. E.J., Ekott, E.J. and Akpan, M.E. (2011). Inhibition and control of microbiologically influenced corrosion in oilfield materials. *Environmental Research Journal* 5(2): 59-65.

Barton, L.L. (1997). *Sulphate reducing bacteria. International Workshop on Industrial Biofouling and Biocorrosion.* Mulheim, Germany, September, 1997.

Beech, I.B. and Flemming, H. (2000). Microbial influenced corrosion of industrial materials (Microbiological fundamentals) available in http://www.efcweb.org/efcweb_media/ Downloads/ EFC+WP10/MICbook.pdf

Cook, T.D. and Campbell, D. T. (1979). Quasi experimentation: Design and analysis issues for field settings. Chicago Illinois

Domsch, K.H. and Gams, W. (1970). *Fungi in Agricultural Soils* (First Edition). Longman Group Limited, London, pp. 20 - 152.

Fawole, M.O. and Oso, B.A. (1998). *Laboratory Manual of Microbiology.* Spectrum books limited, Ibadan, Nigeria, pp. 16-35.

Geiger, S.L., Ross, T.J. and Barton, L.L. (1993). Environmental Scanning electron microscope (ESAM), evaluation of crystal and plaque formation associated with biocorrosion. *Microscience Research Technology,* 25:429-433.

Holt, J.G. Krieg, N.R., Sneath, P.H.A., Staley, J.T. and Williams, S.T. (1994). *Bergy's Manual of Determinative Bacteriology.* Williams and Wilkins Publishers, Maryland.

Huggins, P.E.R.J. (2010). *Microbiologically Influenced Corrosion. What it is and how it works.* American Fire Springler Association, USA.

Oyeleke. S.B. and Manga, B.S. (2008). *Essentials of Laboratory Practicals in Microbiology* (First edition). Tobest Publisher Minna, Nigeria, pp. 28-62.

Postgate, J.R. (1966). Media for sulphur bacteria. *Laboratory Practical* 15, 1239-1244.

Starkey, R.L. (1935). Isolation of some bacteria which oxides thiosulphate. *Soil Science,* 39: 197-218.

Videla, H.A. (2001). Microbiologically induced corrosion: an updated overview, *International Biodeterioration and Biodegradation,* 48: 176-201.