



Studies on the drinking water used in Qalubia and new trend to biotreatment

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Abstract

Contamination of groundwater with heavy metal and Surface water pollution is so dangerous matter that all must face and find solutions for that. This study aims to use develop more safe methods for water treatment using biological treatment as special nanocomposite. Total hardness was 448 mg/L and after treatment reduced to 360 mg/L, while electric conductivity before treatment was 1507 us/cm and decreased to 1369 us/cm., TDS was 994.6 mg/L and after treatment reduced to 903.5 mg/L and chlorides for raw water was 260mg/L and treated water recorded 160 mg/L. Also, iron recorded 0.5 mg/L and reached 0.03 mg/L after treatment and manganese was 0.35 mg/L and reduced to 0.1mg/L after treatment. In River Nile water electric conductivity recorded 409 us/cm and after treatment reported 387 us/cm, while TDS was 269 mg/L before treatment and after treatment recoded 255.4 mg/L. Moreover, total alkalinity before treatment was 200 mg/L and after treatment reduced to 180 mg/L, while iron in water was 0.4 mg/L and decreased to 0.08 mg/L after treatment. The bacterial species isolated from River Nile were *Aeromonassobria*, *Pseudomonas putida*, *leclerciaadecarboxylata*, *Escherichia coli*, *Staphylococcus aureus*, while in Sheblanga Wall water *Staphylococcus hominis*, *sphominis*, *Aeromonassobria*, *Staphylococcus aureus* were isolated. After biological tretment no bacteria found, 0 *Salmonella*, 0 *Shigella*. These results showed that nanocomposite can be used as safe methods in water treatment.

INTRODUCTION

Surface water is the main source of drinking water in Egypt involved in River Nile, its branches and canals like Ismailia Canal. Ismailia Canal water is used for drinking for millions of people living in Cairo, Shupra El-Kheima, Mattaria, Musturod, Abu- Zaabal, Inchas, Belbeis, Abbasa, Abu-Hammed, Zagazeeg, El-Tell El-Kabier, and finally the three cities of canal; Port Said, Ismailia and Suez. And many of area in Egypt behind on groundwater as asource of water drinking .but many ground water contamination with heavy metal so we used several method of treatment to water such as chemical and biological treatment.

MATERIALS & METHODS

Sampling procedure:

Samples were collected from River Nile and Sheblanga Well ground water, Egypt. Sampling was carried out according to Standard Methods for Examination of Water and Wastewater (APHA, 2005). Sodium thiosulphate was added to chlorinated samples to a final concentration 0.1% to neutralize the residual chlorine and prevents contamination of bactericidal action during transit. and to iron and manganese analyses Sample may be preserved by adding 0.5 ml of concentrated nitric acid per 100 ml of sample . This lower PH to less than 2 and will preserve the sample for up to six months.

Physicochemical assessment of water samples

Physicochemical parameters were measured using the method described by APHA, (2005). **Temperature** was using a manual thermometer (110°C) graduated to 0.1°C. **Turbidity** was measured directly by using a digital turbidity meter (HACH 2100N Turbid meter).

PH was measured directly by using a digital pH meter (WTW PH meter). **Conductivity and TDS** were measured directly by using a digital meter (Thermo Scientific) **Hardness** titration with EDTA, **Alkalinity** titration against 0.2N HCL, - **Chlorides** Titrate against AgNO₃, - **Iron** and **Manganese** were measured color by (SHIMADZU - UV-Spectrophotometer).

Bacteria isolation and identification:

Different bacterial isolates were detected, isolated, purified and confirmed at Reference Laboratory for Drinking Water in Egypt to total plat count used Nitrant agar **Most probable number (MPN) method** (APHA, 1995) used Lauryltryptose broth to determination to total coliform and used brilliant green lactose bile broth to determination of fecal coliform , isolation of colonies on **Agar slant and make gram stain to each isolate finally make identification by VITEK 2 systems**

Many species of Bacteria were found in River Nile and Sheblanga Well disappeared after biological treatment

Treatment of trace metals using nanocomposite:

The sample which collected from Sheblanga well and River Nile. Iron, manganese, concentration in that sample was determined by (SHIMADZU - UV- Spectrophotometer). As previous using the method described by (APHA, 2005). The nanocomposites was added to the tested water sample by 20 g/L for 5 h with aeration using air supply. An appropriate sample was taken after 1, 2, 3, 4 and 5 to be tested for detected trace metals.

RESULTS

Physicochemical assessment of water samples:

Temperature (°C) the range of air temperature of River Nile during sample collection in 2014 is (17.8 - 26 - 27.8) the highest value in August and the lowest in January. And in Sheblanga well ranged from (16 - 24.5- 26) the highest value in August and the lowest in January .

Turbidity (NTU) Nephelometric turbidity unit the turbidity concentration values of river Nile during the period of samples collection are (3.4- 9.6 -5.9) (NTU) the highest value is 9.6 (NTU) in June and the lowest is 3.4 (NTU)

in January, and in Sheblanga Well are (4 - 2.3 -6.1) (NTU) the highest value is 6.1(NTU) in August and the lowest is 2.3(NTU) in June. (**pH**).The hydrogen ion concentration (pH) values of River Nile are (8 - 8.6 -7.8) the highest value is 8.6 in June and the lowest value is 7.8 in August, and in Sheblanga Well are (7.7 - 8) during the period of samples collection the highest is 8 in August and the lowest is 7.7 in January

The dissolved oxygen in River Nile is 5.624 mgO₂/L And in Sheblanga Well is 6 mgO₂/L The data recorded in table of the Biochemical Oxygen Demand (BOD)in River Nile is 2.351 mgO₂/L And in Sheblanga Well is 8mgO₂/L .

Chemical Oxygen Demand (COD),the chemical Oxygen Demand (BOD)sin River Nile is 16 mgO₂/L And in Sheblanga Well is 37.6 mgO₂/L**Total hardness (mg / L)**the Total hardness values of River Nile are (185-148-144) the highest value is 185mg/l in January and the lowest value is 144 mg/Lin August, and in Sheblanga Well are (490-320-300) during the period of samples collection the highest is 490 mg/L in January and the lowest is 300mg/L in August **Calcium hardness (mg / L)** , the Calcium hardness values of River Nile are(95 -80-73) the highest value is 95mg/l in January and the lowest value is 73 mg/Lin August, and in Sheblanga Well are(322-320-300)during the period of samples collection the highest is 322 mg/L in January and the lowest is 300mg/L in August. **Total magnesium hardness (mg/L)** total magnesium hardness of values of River Nile are (9-68-71) the highest value is 9 0mg/l in January and the lowest value is 68 mg/Lin June, and in Sheblanga Well are (168-44-140) during the period of samples collection the highest is 168 mg/L in January and the lowest is 44mg/L in June. **Total alkalinityCaCO₃**total alkalinity CaCO₃values of River Nile are(176-200-180) the highest value is 200mg/l in June and the lowest value is 176mg/Lin January, and in Sheblanga Well are(474-300-380)during the period of samples collection the highest is 474 mg/L in January and the lowest is 300mg/L in June.

Conductivity) (US/CM) Conductivity values (US / CM)of River Nile are(415-409-448) the highest value is 448(US/CM) in August and the lowest value is 409(US/CM)in June, and in Sheblanga Well are(917-1507-1484)during the period of samples collection the highest is 1507(US/CM)in June and the lowest is917(US/CM)in January.

TDS total dissolved solids of River Nile are(273.9-269-295.68) the highest value is 295.68mg/L in August and the lowest value is 269 mg/Lin June, and in Sheblanga Well are(605-994.6-913.4) mg/l during the period of samples collection the highest is 994.6 mg/l in June and the lowest is 605mg/l in January.

Chloridesvalue of River Nile are(21.5-30-26) mg/l the highest value is 30mg/L in Juneand the lowest value is 21.5mg/Lin January, and in Sheblanga Well are(178.5-260-160) mg/Lduring the period of samples collection the highest is 260 mg/l in June and the lowest is 160 mg/lin August.

Iron content of River Nile are(0.34-.4-2.94)mg/l the highest value is 2.94mg/L in August and the lowest value is 0.34mg/Lin January, and in Sheblanga Well are(0.38-0.57-0.75)during the period of samples collection the highest is 0.75 mg/l in August and the lowest is 0.38 mg/l in January **Manganese content** :of River Nile are(0.25-0-0)mg/L the highest value is 0.25 mg/L in January and the lowest value is 0mg/Lin June, and in Sheblanga Well are(1.56-0.35-0.69)mg/L during the period of samples collection the highest is 1.56 mg/l in January and the lowest is 0.35 mg/l in June .

Table 1 -physical and chemical parameter before and after treatment with nanocomposite

Parameter	A	B	C	D	Normal range
Temperature °C	27.2		26		
Turbidity(NTU)	2.3	5	9.6	12.8	1
Cl (mg/L)	0.7	0.0	0	0.0	5
PH	7.7	8.5	8.6	9	8.5-6.5
Conductivity(US/Cm)	1507	1369	409	387	1515
TDS(mg/L)	994.6	903.5	269	255.4	1000
Chlorides(mg/L)	260	160	30	70	250
Total alkalinity(mg/L)	300	400	200	180	150
Total hardness(mg/L)	448	360	148	260	500
Calcium hardness(mg/L)	320	320	80	110	350
Magnesium hardness(mg/L)	44	30	68	150	150
Calcium ions(mg/L)	128	128	32	44	140
Magnesium ions(mg/L)	10.56	7.2	16.32	36	36
Iron content(mg/L)	0.571	0.031	0.4	0.08	0.3
Manganese content(mg/L)	0.35	0.10	0	0	00.4

A=before biological treatment to Sheblanga well water
 B=After biological treatment to Sheblanga Well water
 C= Before biological treatment to River Nile water
 D= After biological treatment to River Nile water

Table.2. Compared between the methods of treatment to Nile water by using chemical method and biological method of treatment

Parameter	D	E	limit
Temperature °C		27.3	
Turbidity(NTU)	12.8	0.2	1
Cl (mg/L)	0.0	0.0	5
PH	9	7.5	8.5-6.5
Conductivity(US/Cm)	387	421	1515
TDS (mg/L)	255.4	277.8	1000
Chlorides(mg/L)	70		250
Total alkalinity(mg/L)	180	170	150
Total hardness(mg/L)	260	124	500
Calcium hardness(mg/L)	110	98	350
Magnesium hardness(mg/L)	150	36	150
Calcium ions(mg/L)	44	39.2	140
Magnesium ions(mg/L)	36	8.64	36
Iron Content(mg/L)	0.08	0.1120	0.3
Manganese Content(mg/L)	0	0	0.4

D= After biological treatment to River Nile water

E=After chemical treatment to River Nile Water

Bacteria isolation and identification:

In the present study, different selective media were used as mentioned to isolate most indicator bacteria. All bacterial isolates were purified and maintained on nutrient agar (Oxide Ltd.–UK) and then identified in the present study, VITEK 2 systems used to identification of bacteria isolation. The result as the following

Table 3 Occurrence of bacteria in different drinking water sample

Parameter	A	B	C	D	limit
Total bacterial count at 22°C (CFU /ml)	0.073x10 ³	0.011x10 ³	1.3x10 ³	0.053x10 ³	<0.05x10 ³
Total bacterialcount at 37°C (CFU/ml)	0.285x10 ³	0.020x10 ³	2.75x10 ³	0.69x10 ³	<0.05x10 ³
Total coliform (MPN/100ml)	5.1	2.2	35x10 ³	16	<1.1
Fecal coliform (MPN/100ml)	2.2	<1.1	23	1.1	<1.1

A=before biological treatment to Sheblanga well water
 B=After biological treatment to Sheblanga Well water
 C= before biological treatment to River Nile water
 D= After biological treatment to River Nile water

Table.4 Detection of pathogenic bacteria in different drinking water samples

Pathogenic Bacteria	A	B	C	D
<i>Aeromonassobria</i>	+	-	+	-
<i>Pseudomonas putida</i>	-	-	+	-
<i>leclerciaadecarboxylata</i>	-	-	+	-
<i>Escherichia coli</i>	-	-	+	-
<i>Staphylococcus aureus</i>	+	-	-	-
<i>Staphylococcus hominis</i>	+	-	-	-
<i>Salmonella</i>	-	-	-	-

A=before biological treatment to Sheblanga well water
 B=After biological treatment to Sheblanga Well water
 C= before biological treatment to River Nile water
 D= After biological treatment to River Nile water

After biological tretment

The treatment using nanocomposite decreased the concentrations of heavy metals under study to a limit could not be detected using inductively single Plasma-Optical Emission Spectroscopy. This was due to the nanocomposite used here has a high surface activity that enable it to adsorb organic and inorganic matter dissolved in water besides the adsorption of microorganisms (natural flora) from water. The bioreaction of the microorganisms accumulated on the

nanocomposite in the presence of continuous aeration leads to oxidation of the pollutants. The two trends may be due to that normal flora in the water sample utilized mainly cadmium, cobalt, copper and lead so their concentrations decreased rapidly with time but take a time to adapt the other heavy metals (iron, manganese, ...) so the decrease of these metals showed two regions; the first that had low decrease in concentration with time and that may be the adaptation period and the second that had high decrease in concentration with time due to the increased ability of microorganisms to uptake these three metals.

Discussion

Temperature is a factor of great importance for aquatic ecosystem, as it affects the microorganism as well as physicochemical properties of water (**Delince, 1992**). The temperature values of air and water were affected by the climatic conditions, sampling time and sun shine hours. The range of air and water temperature of River Nile during sample collection in 2014 is (17.8 - 26 - 27.8) the highest value in August and the lowest in January. And in Sheblanga well ranged from (16 - 24.5- 26) the highest value in August and the lowest in January. These result agree with (Elewa and Mandi, 1988, Kobbia et al., 1991, Mohamed Abdo, 2005, Said Daboor, 2006, Shawky, 2007, and S.M. Daboor, 2008)

In the present study, the turbidity concentration values of river Nile during the period of samples collection are (3.4- 9.6 -5.9) the highest value is 9.6 in June and the lowest is 3.4 in January, and in Sheblanga Well are (4 - 2.3 -6.1) the highest value is 6.1 in August and the lowest is 2.3 in June.

Hydrogen ion concentration (pH) was one of the most important and frequently used tests in water chemistry. Changes in pH values beyond the optimal range may affect the microbial physiology. The results of pH values represented that there is a slightly variation among different regions and trend to alkaline side that agree with (**Abdo, 2002**). The hydrogen ion concentration (pH) values during the period of samples collection, of River Nile are (8 - 8.6 - 7.8) the highest value is 8.6 in June and the lowest value is 7.8 in August, and in Sheblanga Well are (7.7 - 8) during the period of samples collection the highest is 8 in August and the lowest is 7.7 in January. May be related to the photosynthetic activity which reduces the CO₂ amount in water (**El-wakeel & Wahby, 1970**). On the other hand the relative decrease of pH values may be due to the drought period leading to the decrease of water level which leading to decomposition of organic matter and high solubility of carbon dioxide in water decrease of pH values (**Abdo, 2002**). The result within limits of (**WHO, 2007** and **Egypt State of Environment Report, 2008**)

Dissolved oxygen was one of the key factors of life; moreover, oxygen is essential for the survival of almost all microorganisms. The susceptibility of fish to toxicity by chemicals increases at low oxygen concentration. Oxygen is also needed for all oxidation, nitrification and decomposition processes, DO are controlled by photosynthesis, respiration and exchange at the air water interface (**Erez et al., 1990**). Dissolved oxygen in River Nile is 5.624 mgO₂ /L and in Sheblanga Well are 6 mgO₂/L. The result within limits of (**WHO, 2007** and **Egypt State of Environment Report, 2008**)

Biochemical Oxygen Demand (BOD)₅, is a measure of amount of oxygen used by microorganism in respiration, the oxidation of organic matter as well as further metabolic (oxidative) pathway of the cellular components synthesized from the wastes (**APHA, 1995**). The Biochemical Oxygen Demand (BOD) in River Nile is 2.351 mgO₂ /L

and in Sheblanga Well are 8 mgO₂/L. The result within limits of (WHO, 2007 and Egypt State of Environment Report, 2008)

Chemical Oxygen Demand (COD) is used to measure the oxygen equivalent of organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant (APHA, 1995). River Nile is 16 mgO₂/L and in Sheblanga Well are 37.6 mgO₂/L. The decreases of COD values at .respectively may be returned to the decomposition of organic matter with the increase of temperature values (Abdo, 2002). This may be explained by the increase of the decomposition of organic matter due to the temperature increasing that was in the line of (Ali, 1998). Also the increasing of COD values during January and July may be returned to the flood period containing a huge amount of organic matter, also it attributed to photosynthesis activity.) The result within limits of (WHO, 2007 and Egypt State of Environment Report, 2008)

Total Hardness of River Nile are (185-148-144) the highest value is 185mg/l in January and the lowest value is 144 mg/L in August, and in Sheblanga Well are (490-320-300) during the period of samples collection the highest is 490 mg/L in January and the lowest is 300mg/L in August. The result within limits of (WHO, 2007, Egypt State of Environment Report, 2008)

Calcium Hardness the range of calcium hardness of River Nile are (95 -80-73) the highest value is 95mg/l in January and the lowest value is 73 mg/L in August, and in Sheblanga Well are (322-320-300) during the period of samples collection the highest is 322 mg/L in January and the lowest is 300mg/L in August. The result within limits of (WHO, 2007, Egypt State of Environment Report, 2008)

Magnesium hardness River Nile are (9-68-71) the highest value is 90mg/l in January and the lowest value is 68 mg/L in June, and in Sheblanga Well are (168-44-140) during the period of samples collection the highest is 168 mg/L in January and the lowest is 44mg/L in June. The result within limits of (WHO, 2007, Egypt State of Environment Report, 2008)

Total alkalinity CaCO₃ of River Nile are (176-200-180) the highest value is 200mg/l in June and the lowest value is 176mg/L in January, and in Sheblanga Well are (474-300-380) during the period of samples collection the highest is 474 mg/L in January and the lowest is 300mg/L in June. , my result within limits of (WHO, 2007, Egypt State of Environment Report, 2008)

Conductivity (US / CM) of River Nile are (415-409-448) the highest value is 448(US/CM) in August and the lowest value is 409(US/CM) in June, and in Sheblanga Well are (917-1507-1484) during the period of samples collection the highest is 1507(US/CM) in June and the lowest is 917(US/CM) in January. My result within limits of (WHO, 2007, Egypt State of Environment Report, 2008)

Total dissolved solids (TDS) of River Nile are (273.9-269-295.68) the highest value is 295.68mg/L in August and the lowest value is 269 mg/L in June, and in Sheblanga Well are (605-994.6-913.4) during the period of samples collection the highest is 994.6 mg/l in June and the lowest is 605mg/L in January. My result within limits of (WHO , 2007 ,Egypt State of Environment Report, 2008)

Chloride value of River Nile are (21.5-30-26) the highest value is 30mg/L in June and the lowest value is 21.5mg/L in January, and in Sheblanga Well are (178.5-260-160) during the period of samples collection the highest is 260 mg/l in

June and the lowest is 160 mg/l in August my result within limits of (WHO , 2007 ,Egypt State of Environment Report, 2008).

Iron content of River Nile are(0.34-1.4-2.94) the highest value is 2.94mg/L in August and the lowest value is 0.34mg/L in January, and in Sheblanga Well are(0.38-0.57-0.75)during the period of samples collection the highest is 0.75 mg/l in August and the lowest is 0.38 mg/l in January ..My result within limits of (WHO , 2007 ,Egypt State of Environment Report, 2008)

Manganese content of River Nile are(0.25-0-0) the highest value is 0.25 mg/L in January and the lowest value is 0mg/L in June, and in Sheblanga Well are(1.56-0.35-0.69)during the period of samples collection the highest is 1.56 mg/l in January and the lowest is 0.35 mg/l in June.My result within limits of (WHO , 2007 ,Egypt State of Environment Report, 2008)

Treatment of heavy metals using nanocomposite

The treatment using nanocomposite decreased the concentrations of heavy metals under study to a limit could not be detected using Inductively Coupled Plasma-Optical Emission Spectroscopy. This was due to the nanocomposite used here has a high surface activity that enable it to adsorb organic and inorganic matter dissolved in water besides the adsorption of microorganisms (natural flora) from water. The bioreaction of the microorganisms accumulated on the nanocomposite in the presence of continuous aeration leads to oxidation of the pollutants. The two trends may be due to that normal flora in the water sample utilized mainly cadmium, cobalt, copper and lead so their concentrations decreased rapidly with time but take a time to adapt the other heavy metals (barium, nickel and zinc) so the decrease of these three metals showed two regions; the first that had low decrease in concentration with time and that may be the adaptation period and the second that had high decrease in concentration with time due to the increased ability of microorganisms to uptake these three metals.

Microbiological assessment of water samples

The obtained results indicated that the values of total viable bacterial counts (TVBC) determined at 22°C were higher than those determined at 37°C. The optimum temperature for the bacterial population which can grow at the human and animal bodies is 37°C. Whereas at 22°C, most of air and soil bacteria can grow well, in addition to the human and animal bodies bacteria. This may explain why the numbers of bacteria counted at 22°C were much higher than those determined at 37°C. These results are in agreement with those reported by Sabae and Rabeh (2007); Abdoet al., (2010) and Azzam (2010).

Total viable bacterial count at 22°C were found to be 1.3×10^3 CFU/mL in River Nile after biological treatment to River Nile became 0.053×10^3 CFU/mL. In Sheblanga Well was found to be 0.073×10^3 CFU/mL after biological treatment to Sheblanga Well was found to be 0.011×10^3 CFU/mL.

Total spore-forming bacterial count at 37°C were found to be 2.75×10^3 CFU/mL in River Nile .After biological treatment to River Nile water became 0.69×10^3 CFU/mL. In Sheblanga Well was found to be 0.285×10^3 CFU/mL, from tap in Sheblanga(TSB) was 0.385×10^3 CFU/mL. After biological treatment to Sheblanga Well water (TSB) was 0.020×10^3 CFU/mL .

Faecal bacteria are considered to be good indicators of faecal contamination as they present in the faeces of humans and warm-blooded animals. Total coli forms faecal coli forms and faecal *Streptococci* are indicator bacteria that have been used for decades to infer the presence of other potentially harmful pathogens in recreational water (**Noble et al., 2004, Mutlak et al., 1980, Sabae (I)2000**).

Most Probable Number of total coliform bacteria /100ml at 37°C were found to be 35×10^3 MPN/100ml in River Nile. After biological treatment to River Nile water became 16 MPN/100mL. In Sheblanga Well was found to be 5.1 MPN/100mL, from tap in Sheblanga (T.C) was >23 MPN/100mL. After biological treatment to Sheblanga Well water (T.C) was 3.6 MPN/100mL.

Most Probable Number of fecal coliform bacteria /100ml at 37°C were found to be 23 MPN/100ml in River Nile. After biological treatment to River Nile water became 1.1 MPN/100mL. In Sheblanga Well was found to be 2.2 MPN/100mL, from tap in Sheblanga (T.C) was >23 cell/100mL. After biological treatment to Sheblanga Well water (T.C) was <1.1 MPN/100mL.

Considerable public health rash can be associated from dealing with water contaminated water contaminated with fecal coliform $>2 \times 10^2$ CFU/ 100 mL. This includes ingestion of contaminated water or body contact with polluted recreational waters which increase the chance of developing illness from pathogens entering the body through the mouth, nose, ears, or cuts in the skin (**Geldreich, 1996**).

The highly undesirable levels of contamination found even in protected surface water may have a count of more than 1000 fecal coliform per 100 mL. In some instances, it may be relevant to supplement the fecal coliform count with measurements of other groups of organisms, e.g. fecal streptococci. However, the fecal streptococci include other species which may multiply in soil and surface water, especially in combination with plant debris decay material. The streptococci of fecal origin have a longer survival time in ground water than fecal coliform (**Azzam, 2010**).

Among the three primary bacterial indicators, total coliforms represented the highest values followed by fecal coliforms and fecal streptococci, also TVBCs at 22°C recorded higher density than at 37°C at all sites. These results are in agreement with those reported by **Salah El-Din (2005) and Azzam (2010)**.

Coliforms were always presented in sea water during all seasons (**El-Jarousna, 2006**). A seasonal variation was observed in a study on Damietta branch in Egypt in which the highest densities of coliforms were recorded during summer and the lowest were recorded during winter (**Sabae and Rabeh, 2007**).

Many of Bacteria and heavy metal were reduced by biological treatment to water by nanocomposites. The cell walls of Gram negative and Gram positive bacteria consist of an anionic matrix of biopolymers such as peptidoglycan, teichoic acid, teichuronic acid, phospholipid and lipopolysaccharide as well as various polypeptides and polysaccharide. The wall polymers enable bacteria to sorb and bind significant amounts of metals from their surroundings (**Mayers and Beveridge, 1989**). Also no generalizations regarding differences between Gram negative and Gram positive for heavy metals sorption (metal removal by one or more process) (**Mullen et al., 1989**).

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