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Reverse Osmosis Units in an Urban Area - A Case Study

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Abstract: A number of water samples from existing sources of supply at Nagpur were examined for their physical and chemical properties in ETC laboratory before and after treatment by Reverse Osmosis (RO) units. Data was collated and analyzed in view of a WHO warning on RO water. It was observed that RO water is invariably acidic, corrosive and contains free CO_2. This water quality, if used by domestic consumers requires caution as per WHO warning. Hospitals requiring RO water for dialysis may ensure its proper storage and transmission of RO water in view of its corrosive nature and also ensure disinfection during storage.

I. INTRODUCTION

Growing urbanization of cities/towns has raised demand for additional water supply and for improvement in urban and rural liquid/sewage/grey water and solid management systems. Environmental awareness amongst masses has increased and demand for safe drinking water quality has increased.

Modern-day advertising- world has been insisting on use of domestic reverse osmosis (RO) units. Many hotels and restaurants also serve RO treated water.

Hospitals have installed such units for dialysis units. RO units assure clean, pure and healthy water. A complete RO unit should has a carbon filter for removal of organics if any, a semi-permeable membrane for removal of dissolved inorganics and a UV light for disinfection.

Main sources to Nagpur city water supply are the Kanhan river and the Pench irrigation reservoir. Besides there are a number of dug wells and bore wells being used as water supply sources to residential areas/colonies over city fringe areas.

A. Purpose Of The Paper

Laboratory at Enviro Techno Consult, Nagpur, an "in-house R & D unit", recognized by DSIR, has been receiving a number of water samples for their chemical analyses and suitability for drinking.

Only properly labeled indicating a) agency, b) source of water sample, c) date of collection and d) storage details etc. were accepted. It was decided to examine data on chemical quality of input and output of RO units in Nagpur city according to respective water sources.

II. METHODOLOGY

Samples were delivered by from the above mentioned sources were analyzed for routine physical-chemical parameters. Most consumers wanted to know i) if RO was required as per observed water quality of the sample/ source or ii) the efficiency of the installed RO units.

Analyses were carried out as prescribed by Her Majesty's Stationary Office [i], GEMS/water operational guide [ii], Standard Methods for examination of water & Wastewaters [iii].

III. RESULTS

Averages and standard deviations of chemical quality parameters of water supplied by Nagpur Municipal Corporation (NMC), of dug and bore well water are included in Tables 1, 2 and 3 respectively.

TABLE 1
NMC-Water quality

Parameters*	Range	Average	Standard deviation
pH	7.2-7.7	--	--
Conductivity, µS	230-499	288	104
Total dissolved solids	115-274	163	59
MO alkalinity as $CaCO_3$	44-282	106	90
Total Hardness as $CaCO_3$	90-190	118	36
Ca Hardness as $CaCO_3$	64-120	76	22
Mg Hardness as $CaCO_3$	24-70	42	15
Ca^{++}	26-48	35	12
Mg^{++}	9-17	12	4
Chloride as Cl^-	9-49	24	14
Sulphates as SO_4^{--}	10-18	12	3
Total Iron as Fe	Nil	--	--
Silica	0.4-4.8	2.6	--
Fluoride	0.1-0.3	0.3	0.1

N.B. All values in mg/L except pH or otherwise stated; residual chlorine was absent in all samples;
*parameters asked by the client

Table 2
Dug wells - water quality, Nagpur

Parameters*	Range	Average	Standard deviation
pH	7.1-8.8	--	--
Conductivity, µS	220-1305	805	302
Total dissolved solids	166-1266	679	314
MO alkalinity as $CaCO_3$	106-504	282	116
Total Hardness as $CaCO_3$	114-460	274	117
Ca Hardness as $CaCO_3$	46-272	156	85
Mg Hardness as $CaCO_3$	24-188	122	49
Ca^{++}	18-109	62	34
Mg^{++}	5-45	29	12
Chloride as Cl^-	29-99	56	30
Sulphates as SO_4^{--}	7-56	28	16
Total Iron as Fe	0-0.2	0.1	0.1
Silica	2.9-16	9.7	4.9
Fluoride	0.3-1.2	0.7	0.3

N.B. All values in mg/L except pH or otherwise stated; *parameters asked by the client

Table 3
Bore well- Water quality

Parameters*	Range	Average	Standard deviation
pH	7.0-7.8	--	--
Conductivity, µS	606-3280	1382	776
Total dissolved solids	492-1952	999	442
MO alkalinity as $CaCO_3$	78-488	246	138
Total Hardness as $CaCO_3$	188-480	360	131
Ca Hardness as $CaCO_3$	75-395	222	93
Mg Hardness as $CaCO_3$	45-380	150	91
Ca^{++}	30-158	88	37
Mg^{++}	11--91	33	20
Chloride as Cl^-	34-845	219	254
Sulphates as SO_4^{--}	13-242	77	70
Total Iron as Fe	Traces	-	---
Silica	2-14	8.3	5.1
Fluoride	0.4-1.4	0.8	0.5

N.B. All values in mg/L except pH or otherwise stated; *parameters asked by the client

Results of analysis of RO output water irrespective of source were analyzed in order to get an idea of its average quality and is given in Table 4.

Table 4
Water quality – RO output

Parameters	Range	Average	Standard deviation
pH	5.1-7.3	--	--
Conductivity, µS	9-83	26	18
Total dissolved solids	5-46	12	9
MO alkalinity as $CaCO_3$	0-96	19	24
Total Hardness as $CaCO_3$	0-68	15	15
Ca Hardness as $CaCO_3$	0-14	7	6
Mg Hardness as $CaCO_3$	0-60	9	14
Ca^{++}	0-8	3	3
Mg^{++}	0-14	2	3
Chloride as Cl^-	0-18	9	5
Sulphates as SO_4^{--}	0-10	3	4
Total Iron as Fe	Traces	--	--
Silica	0-3	1	1
Fluoride	0-0.2	0.2	--

N.B. All values in mg/L except pH or otherwise stated,

IV. DISCUSSION

Comparison of RO input water quality as per the sources [surface, shallow aquifer (dug wells) and deeper aquifer (bore wells)] is included in Table 5.

Table 5
Averages of chemical parameters

Parameters	Source		
	NMC	Dug well	Bore well
pH	7.2-7.7	7.1- 8.8	7.0-7.8
Conductivity, µS	288	805	1382
Total dissolved solids	163	679	999
MO alkalinity as $CaCO_3$	106	282	246
Total Hardness as $CaCO_3$	118	274	360
Ca Hardness as $CaCO_3$	76	156	222
Mg Hardness as $CaCO_3$	42	122	150
Ca^{++}	35	62	88
Mg^{++}	12	29	33
Na^+ by calculation	7	53	127
Chloride as Cl^-	24	56	219
Sulphates as SO_4^{--}	12	28	77
Total Iron as Fe	nil	0.1	--
Silica	2.6	9.7	8.3
Fluoride	0.3	0.7	0.5
Ionic load	6	16	25
Residual chlorine	--	--	--
Probable composition of residue,	100	257	336

N.B. All values in mg/L except pH or otherwise stated

Average water quality of i) NMC supply, ii) dug wells and iii) bore wells included in Table 4 indicates that NMC water quality is typical of a surface water source. It has lower conductivity than that in dug and bore well samples. Conductivity indicates total dissolved solids. Ground water remains in contact with local geology for longer periods in both dug and bore wells which is why ionic load is higher in ground waters both dug and bore wells. Comparison of water quality from all the sources with that in IS 10500[IV] for drinking water indicates that water quality in all sources is within permissible limits.

Any water leaves a residue or forms scales during its use e.g. scales on heating element, plumbing joints, inside the pipe line etc. Probable composition of likely residues during water-use from above mentioned sources was calculated. It was found that predominant residue of water from all the sources would be $CaCO_3$ and Mg CO_3 which have been included in Table 4. Each litre of water sample after evaporation would leave scales of $CaCO_3$ and $MgCO_3$ @ 100, 257 and 333 mg/L in NMC, dug well and bore well waters respectively.

Calcium carbonate stability index: It is useful to inquire if water from any source is corrosive or scale forming. Commonly used indices to find tendency of water to form scales are Langelier index (LI) and Ryzner index (RI).[V] Langelier Saturation Index (LI), is a measure of water's ability to dissolve or deposit calcium carbonate. It is used as an indicator of the corrosive/ aggressive nature of water. The index is related to the deposition of a calcium carbonate film or scale. This covering can insulate pipes, boilers, and other components of a system from contact with water. When no protective scale is formed, water is considered to be aggressive and corrosion can occur.

Highly corrosive water can cause system failures or result in health problems because of dissolved lead and other heavy metals. Excessive scales also can damage water systems, necessitating repair or replacement. LI is valid for stagnant water storage. Negative LI indicates that water is corrosive and positive LI shows scale formation tendency.

Ryzner index RI[V] is empirical and is applicable to flowing systems e.g. within the distribution system in which environment is different from that of stored water. Scale formation would be heavy if RI is less than 5.5; scales would be formed if RI is between

5.5 & 6.2. There would not be any problem if RI is between 6.2 & 6.8. Water would be aggressive if RI is between 6.8 and 8.5 and water would be very aggressive if RI is more 8.5.

Both LI and RI were calculated for average values of NMC, dug well and bore well water and are included in Table 6.

Table 6
Langelier and Ryzner Indices for average water quality

Parameters	NMC pH		Dug well pH		Bore well pH	
pH	7.2	7.7	7.1	8.8	7.0	7.8
LI	-0.7	-0.2	-0.1	+1.6	-0.2	+0.4
RI	8.1	7.7	7.3	5.6	7.4	6.6
Inference	Aggressive		Aggressive	Scale forming	Aggressive	Equilibrium

This table shows that i) NMC water is corrosive , ii) dug well water is likely to be corrosive if its pH is around 7 as per LI and RI. It will be scale forming at higher pH values and that iii) the same is true for bore well water.

Important common water- ingredients and their metabolic functions are given in Table 7. It may be noted that these are also reduced during RO process.

Table 7
Minerals in water and their metabolic functions

Parameters	Input to RO	Output to RO	Reduction %

Mineral	Metabolic function
Calcium	Bone development, nerve impulses transmission, clotting of blood
Magnesium	Bone formation, lipid metabolism and protein synthesis, CVD protection.
Sodium	Regulation of cell permeability and body fluids; excessive intake associated with high blood pressure.
Chloride	Hydrochloric acid formation (digestive juices for digestion process).
Sulphate	Hair and nails formation, cellular respiration
F,Co,Cr^{+6},Fe,Mn,Se	Are also health related and depend on geology of the area in which source is located.

It was found that there are changes in RO output water quality irrespective of the source of water. Drinking water, during metabolic pathways supplies and transports different minerals which have essential functions like bone and teeth mineralization, regulation of hydro-saline balance etc. Table 8 includes the changes in some of these parameters.

Table 8 Changes in water quality due to RO

N.B. All values except pH in mg/L, unless otherwise stated

Table 7 indicates that RO output water can be classified as "acid water" since pH is less than 7 and also as very "soft" since hardness is less than 100 mg/L as $CaCO_3$. This Table also shows that hardness (Ca^{++} and Mg^{++}) removal is about 89-90 per cent and anions (Cl^-, SO_4^{--} & HCO_3^-) removal is between 63 and 77 per cent. There was an increase in free carbon dioxide from 5-17 mg/L in feed water to 4-336 as $CaCO_3$ when calculated from pH and ratio of CO_2 to methyl orange alkalinity [v].

It was observed that pH of RO output water is invariably reduced. This is significant because pH is used to calculate LI/RI which indicates corrosive or scale forming tendency. Ryzner and Langelier indices for RO output water given in **Table 9** indicate that RO output water is highly corrosive irrespective of raw- water source.

Table 9
Langelier and Ryzner Indices of RO treated water

LI	-4.6	-2.4
RI	14.3	12.1

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V. CONCLUSION

It can be concluded that use of only RO treated water for drinking purposes would be in contradictory to the opinions expressed in a WHO publication [vi]. There is a recent warning by WHO vide V4_RO new poster.

It will be advisable that they chose hospitals/ nursing homes to choose proper plumbing system, storage facility and disinfection method during storage since they require RO water for dialysis units as per international/ICMR standards because RO treated water would be invariably corrosive/aggressive.

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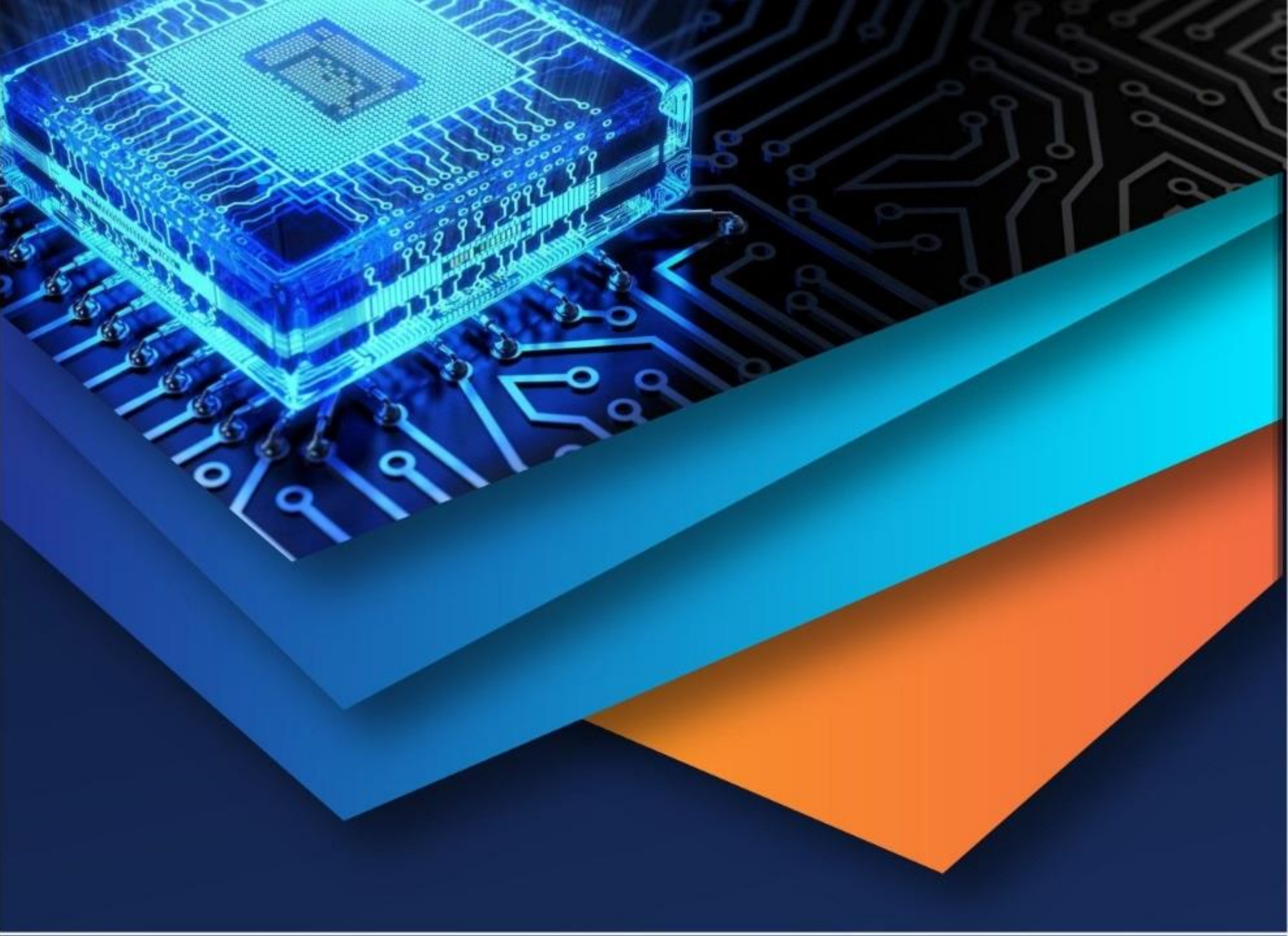

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