

## Evaluation of Heavy Metal Pollution Index (HPI) of Ground Water in and around the Coastal Area of Gulf of Mannar Biosphere and Palk Strait

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### ARTICLE DETAILS

#### Article history:

Received 18 June 2016

Accepted 11 July 2016

Available online 22 July 2016

#### Keywords:

Heavy Metal Pollution Index

Metal Index

Gulf of Mannar

Palk Strait

### ABSTRACT

The concentration of seven eco-toxic heavy metals such as As, Mn, Zn, Cd, Cr, Cu and Pb have been analyzed for 50 ground water sampling stations in and around Gulf of Mannar (GoM) and Palk strait (PS) sea shore area by atomic absorption spectrometer. The concentrations of heavy metals have been found to above the permissible limit of drinking water quality standards. The data have been used for the calculation of Heavy-metal Pollution Index (HPI) and Metal Index (MI). The mean HPI values of ground water in GoM and Palk Strait area are 233.2 and 136.4 respectively. The results indicated that mean HPI values were found to be above the critical pollution index value of 100. Mean deviation and percentage deviation from the mean HPI value was also calculated for each sampling point. HPI results showed that, 60% of the sampling sites at Gulf of Mannar were found higher than the critical pollution index 100, however, in Palk Strait 68% of the sampling sites showed higher than the critical pollution index. The comparative study of these two study areas were also carried out and represented in the form of bar diagram. The mean MI values of ground water at GoM and Palk Strait area are 1.728 and 0.589 respectively. These results of MI were used to ascertain the heavy metal toxicity among the sampling sites.

### 1. Introduction

Water is a vital source of life which is essential for survival of all living organisms. Water is not only the most important essential constituent of all animals, plants and other organisms but also the pivotal for the survivability of mankind in the biosphere [1]. Heavy metals are among the most common environmental pollutants, and their occurrence in water and biota indicate the presence of natural or anthropogenic sources [2, 3]. Heavy metal contamination in water is recognized as a severe environmental problem and therefore the study related to water contamination has become important. The contamination of water by hazardous and toxic metals is harmful for the human consumption [4]. The pollution parameters are generally monitored for the assessment of quality of any system which gives an idea about the pollution with reference to particular parameters. Quality indices are useful in getting a composite influence of all parameters of overall pollution. It also makes the assessments into a reproducible form and compile all the pollution parameters into some easy approach. Several methods have been performed to develop quality indices for estimation of water quality with respect to water quality parameters [5-9]. In recent years much attention has been given to the evaluation of heavy metal pollution in ground water and surface water by using the heavy metal pollution index (HPI) [10, 11]. Heavy metal pollution index (HPI) is defined as a rating reflecting the composite influence of different dissolved heavy metals [12]. HPI is calculated from a point of view of the suitability of ground water for human consumption with respect to metal contamination. HPI is a powerful tool for ranking amalgamated influence of individual heavy metal on the overall water quality [13] and a view of the suitability of ground water for human consumption [14]. The critical pollution index value for drinking water should be less than 100.

Another index is the general metal index (MI) for drinking water [15], which takes into account possible additive effect of heavy metals on human health that help to quickly evaluate the overall quality of drinking water. The higher the concentration of metals with respect to MAC

(Maximum Allowed Concentration) value which makes the worse quality of the water. Therefore, the value of 1 for MI is a threshold of warning even in the case where  $C_i$  is less than  $MAC_i$  for all elements. (Where  $C_i$  is mean concentration of each metal and  $MAC_i$  is maximum allowable concentration). The heavy metal pollution index (HPI) and metal index (MI) for bore and duck well water samples of Gulf of Mannar and Palk Strait coastal area were determined and presented in this paper.

### 2. Experimental Methods

Heavy metals such as Manganese (Mg), Cadmium (Cd), Arsenic (As), Copper (Cu), Chromium (Cr), Lead (Pb) and Zinc (Zn) were determined by AAS [16] and the data were used for this study. The profiles of study area also were well detailed in the previous paper [17]. Fifty sampling locations in Gulf of Mannar (GoM) and Palk Strait (PS) with sample code were given in Table 1.

#### 2.1 Heavy Metal Pollution Index (HPI)

Heavy metal pollution index (HPI) is also a powerful technique for the assessment of water quality on the basis of heavy metal concentration. Heavy metal Pollution Index (HPI) has been developed and formulated [18] as,

$$HPI = \frac{\sum_{i=1}^n W_i Q_i}{\sum_{i=1}^n W_i} \quad (1)$$

$$Q_i = \sum_{i=1}^n \frac{|M_i - I_i|}{S_i - I_i} \times 100 \quad (2)$$

where,  $Q_i$  is the sub-index of the  $i^{\text{th}}$  parameter;  $W_i$  is the unit weightage of the  $i^{\text{th}}$  parameter;  $n$  is the number of parameters;  $M_i$  is the monitored value of heavy metal of  $i^{\text{th}}$  parameter;  $I_i$  is the ideal value of  $i^{\text{th}}$  parameter;  $S_i$  is the standard value of the  $i^{\text{th}}$  parameter. The computational method for calculating HPI is given in the Table 2.

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**Table 1** Sampling Stations in Gulf of Mannar (GoM) and Palk Strait (PS) area

Sample No	Sampling Locations	Type of well	Sample No	Sampling Locations	Type of well
GoM1	Rameshwaram Kovil (Nalatheertham)	Open well	PS1	Devipattinam	Open well
GoM2	Sathya Nagar (Rameshwaram)	Open well	PS2	Thirupalaikudi	Open well
GoM3	Pamban	Open well	PS3	Thondi	Open well
GoM4	Mandapam	Open well	PS4	SP Pattinam	Bore well
GoM5	Seeniyappa Tharga	Open well	PS5	Mimisal	Bore well
GoM6	Pirappan Valasai	Open well	PS6	Manamelkudi	Open well
GoM7	Uchipuli	Open well	PS7	Kattumavadi	Open well
GoM8	Ramanatha-puram (Bharathinagar)	Open well	PS8	Ammanichathiram	Open well
GoM9	Kilakarai	Open well	PS9	Rajamadam	Open well
GoM10	Ervadi	Open well	PS10	Sethubavachathiram	Open well
GoM11	Idhambadal	Pond	PS11	Thuraiyur	Bore well
GoM12	Sikkal	Open well	PS12	Mallipattinam	Bore well
GoM13	Sayalkudi	Hand Pump	PS13	Adhirampattinam	Hand Pump
GoM14	Narippayur	Open well	PS14	Puthukudi	Bore well
GoM15	Vembar	Open well	PS15	Dhamothara-pattinam	Bore well
GoM16	Melmanthai	Hand Pump	PS16	Mutupet	Hand Pump
GoM17	Srivaigunda perumalpuram	Open well	PS17	Nedumbalam	Hand Pump
GoM18	Veppalodai	Hand Pump	PS18	Kokkaladi	Open well
GoM19	Pattinamaruthur	Open well	PS19	Keelaiyur	Open well
GoM20	Tharuvaikulam	Open well	PS20	Thiurpoondi	Bore well
GoM21	Devispuram	Open well	PS21	Velankanni	Bore well
GoM22	Therkusottan thoppu	Open well	PS22	Boothangudi	Hand Pump
GoM23	Saramani Street (Tuticorin)	Hand Pump	PS23	Thiruvasal	Bore well
GoM24	Natarajapuram (Tuticorin)	Hand Pump	PS24	Narimanam	Hand Pump
GoM25	Keelarahaveethi (Tuticorin)	Open well	PS25	Nagapattinam	Open well

**Table 2** HPI Calculation for ground water sample

Heavy metals	Mean Value (ppb) $M_i$	Standard Permissible value (ppb) $S_i$	Highest Desirable Value (ppb) $I_i$	Unit Weightage $W_i$	Sub Index $Q_i$	$W_i \times Q_i$
Mn	60.66	300	100	0.0033	19.67	0.07
Cd	3.33	10	--	0.1	33.33	3.33
As	2.0	50	--	0.02	4.00	0.00
Cu	19.66	1500	50	0.00066	2.09	0.00
Cr	6.0	50	--	0.02	12.00	0.24
Pb	52.66	50	--	0.02	105.33	2.11
Zn	303.6	15000	5000	0.000066	46.96	0.00
				$\sum W_i = 0.164$	$\sum W_i Q_i = 5.69$	

Heavy metal Pollution Index (HPI) =  $5.69/0.164 = 34.7$ . Similarly the HPI values for 50 samples were calculated and the results were given in the Table 4.

## 2.2 Metal Index (MI)

The metal index (MI) was preliminarily defined by Tamasi and Cini [19]. This index can be expressed by the following equation,

$$MI = \sum_{i=1}^N \frac{C_i}{(MAC)_i} \times 100 \quad (3)$$

where MI is the metal index, C is the concentration of each element in solution, MAC is the maximum allowed concentration for each element, and the subscript i is the  $i^{\text{th}}$  sample.

The computational method for calculating Metal Index (MI) for a ground water sample is presented in the Table 3.

**Table 3** MI Calculation for ground water sample

Heavy metals	Concentration (C <sub>i</sub> ) (ppm)	Concentration (C <sub>i</sub> ) (ppb)	Maximum Allowable Conc. (MAC)	$MI = \sum C_i/MAC$
Mn	0.061	60.66	300	0.202
Cd	0.003	3.33	10	0.333
As	0.002	2.0	50	0.04
Cu	0.020	19.66	1000	0.019
Cr	0.006	6.0	50	0.12
Pb	0.053	52.66	50	1.053
Zn	0.304	303.66	15000	0.020
Mean =				0.255

Similarly the MI values for 50 samples were calculated and the results were given in Table 4.

## 3. Results and Discussion

The HPI values for 50 water samples were calculated and the results were tabulated in Table 4 and used to assess the quality of ground water samples. The mean heavy metal pollution indexes (HPI) of Gulf of Mannar and Palk Strait sea shore area 233.2 and 136.4 respectively, which are found above the critical index value 100. Mean deviation and percentage deviation from the mean HPI value has also been calculated for each sampling point and presented in Table 4. This index values confirmed that heavy metal contamination along the coastal area [20].

**Table 4** HPI and MI values of ground water in GoM and Palk Strait sea shore area

S.No	HPI	M.D	% D	MI	S.No	HPI	M.D	% D	MI
GoM1	34.7	-199	-85.12	0.256	PS1	122.6	-13.8	-85.12	0.497
GoM 2	54.0	-179	-76.84	0.314	PS 2	231.8	95.4	-76.84	1.345
GoM 3	37.2	-196	-84.05	0.250	PS 3	61.1	-75.3	-84.05	0.461
GoM 4	89.2	-144	-61.75	0.873	PS 4	109.4	-27	-61.75	0.490
GoM 5	82.2	-151	-64.75	0.676	PS 5	59.8	-76.6	-64.75	0.190
GoM 6	54.4	-179	-76.67	0.296	PS 6	95.7	-40.7	-76.67	0.314
GoM 7	51.4	-182	-77.96	0.495	PS 7	84.3	-52.1	-77.96	0.304
GoM 8	73.6	-160	-68.44	0.774	PS 8	104.5	-31.9	-68.44	0.344
GoM 9	101.1	-132	-56.65	1.157	PS 9	140.3	3.9	-56.65	0.426
GoM 10	178.0	-55.2	-23.67	1.601	PS 10	192.3	55.9	-23.67	0.642
GoM 11	88.4	-145	-62.09	0.875	PS 11	194.1	57.7	-62.09	0.608
GoM 12	110.9	-122	-52.44	1.492	PS 12	87.8	-48.6	-52.44	0.408
GoM 13	116.7	-117	-49.96	1.372	PS 13	146.3	9.9	-49.96	0.822
GoM 14	91.0	-142	-60.98	1.625	PS 14	126.3	-10.1	-60.98	0.598
GoM 15	105.1	-128	-54.93	1.023	PS 15	195.4	59	-54.93	0.736
GoM 16	367.4	134	57.55	1.694	PS 16	87.7	-48.7	57.55	0.657
GoM 17	254.2	21	9.01	1.965	PS 17	217.2	80.8	9.01	0.798
GoM 18	386.5	153	65.74	3.255	PS 18	183.5	47.1	65.74	0.717
GoM 19	471.6	238	102.23	2.831	PS 19	211.8	75.4	102.23	0.906
GoM 20	506.6	273	117.24	2.867	PS 20	212.6	76.2	117.24	0.891
GoM 21	432.5	199	85.46	3.660	PS 21	32.9	-103.5	85.46	0.277
GoM 22	370.5	137	58.88	2.883	PS 22	107.9	-28.5	58.88	0.460
GoM 23	667.2	434	186.11	3.698	PS 23	184.2	47.8	186.11	0.657
GoM 24	816.8	584	250.26	3.915	PS 24	91.8	-44.6	250.26	0.392
GoM 25	288.6	55.4	23.76	3.343	PS 25	129.6	-6.8	23.76	0.773
Mean	233.2			1.728		136.4			0.589

M.D: Mean Deviation, % D: Percentage of Deviation

**Table 5** Water Quality Classification using MI [22 & 23]

MI	Characteristics	Class	Sampling sites at GoM	Sampling Sites at Palk Strait
< 0.3	Very pure	I	GoM 1, 3,6	PS5,21
0.3 - 1.0	Pure	II	GoM 2,4,5,7,8,11	All Sampling Sites except PS2,5,21
1.0 - 2.0	Slightly affected	III	GoM 9,10,12,13,14,15,16,17	PS2
2.0 - 4.0	Moderately affected	IV	GoM18,19,20,21,22,23,24,25	--
4.0 - 6.0	Strongly affected	V	--	--
> 6.0	Seriously affected	VI	--	--

In Gulf of Mannar, approximately 60% of the ground water samples were found above the critical index value 100, particularly the sampling points GoM19, GoM20, GoM23, and GoM24. Heavy metal pollution may be due to leaching of heavy metals from industries like fertilizers, pigments etc., were located in this study area. Mean deviation and percentage deviation results showed that fifteen sampling points (60%) recorded an index value lower than the mean value. The percentage deviation fall on the negative side, this indicates a slightly better quality with respect to heavy metals. Pb and Zn were found to be contributed more in metal pollution.

In Palk Strait sea shore area, 68% of ground water samples reported high HPI value than the critical pollution index 100, sampling sites at PS17, PS19 and PS20 were found to be very high HPI Value. Pb, Cu and Mn were found to be contributed more to the heavy metal pollution. Mean deviation and percentage deviation results showed that fourteen sampling points (56%) recorded an index value lower than the mean and the percentage deviation on the negative side which indicate a slightly better quality with respect to heavy metals [21].

The mean metal index (MI) value of ground water at Gulf of Mannar and Palk Strait sea shore area were found 1.728 and 0.589 respectively. Further individual sampling sites were classified according to the literature (Table 5). The MI results showed that, in Gulf of Mannar the sampling sites GoM18, GoM19, GoM20, GoM21, GoM22, GoM23, GoM24 and GoM25 were observed highly polluted with respect to heavy metals (Table 5). These sampling sites are located in and around Tuticorin city. From the Table 5, it is confirmed that, the above mentioned area in Gulf of Mannar are highly polluted with respect to heavy metal. This is due to the number of large scale industries including thermal power plant, fertilizer, chemical and mineral processing plants, textile mills, match factories and nearly 500 small scale industries are located this study area. In Palk Strait sea shore area, the sampling site PS2 only polluted with respect to heavy metals (Table 5).

Based on the classification and the experimental results (MI), it is suggested that most of the ground water samples in GoM sea shore area has slightly affected with respect to metal pollution. The ground water samples nearby Tuticorin area has moderately affected due to industrial pollution. The mean MI value of ground water in GoM sea shore area is 1.728 which indicates the ground water is slightly affected due to industrial pollution. The mean MI value of ground water in Palk Strait sea shore area is 0.589 which indicates the ground water is in good quality when compared with GoM.

The comparative study also carried out for these two study areas with respect to HPI. The results showed that, most of the sampling sites in GoM were contaminated more when compared to Palk Strait sea shore area (Fig.1).

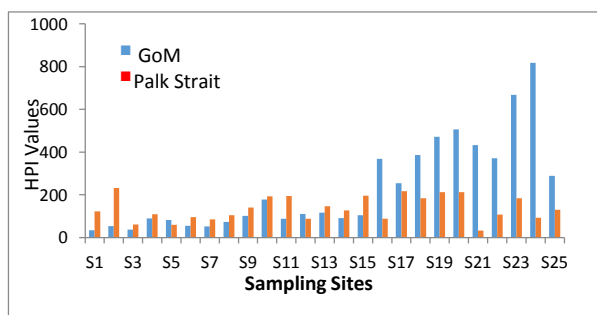


Fig. 1 Combined bar diagram of HPI values for GoM and Palk Strait

In this Gulf of Mannar sea shore area, the higher values of HPI were observed particularly the Tuticorin region. This may due to the sampling sites were located in industrialized area. During the past three decades, there has been a dramatic change in industrial development on the coast due to the establishment of a number of large scale industries including thermal power plants, fertilizer, chemical, textile mills, match factories and nearly 500 small scale industries [24].

#### 4. Conclusion

In the present study, the mean heavy metal pollution index (HPI) of Gulf of Mannar and Palk Strait sea shore area are 233.2 and 136.4 respectively were found above the critical index value 100, which indicates that are represented as ground water pollution with respect to heavy metals. Similarly the mean metal index (MI) values of ground water samples at Gulf of Mannar and Palk Strait sea shore area are 1.728 and 0.589

respectively also reported. The HPI model used here seems to be promising and is proved to be useful tool in evaluating the overall pollution level of ground water in terms of heavy metals. Another index used is the general metal index (MI) which is used to evaluate the ground water samples with respect to heavy metals. This indexing study showed that, GoM were highly polluted when compared to Palk Strait sea shore area.

#### Acknowledgments

The author acknowledges the Management and Principal of Mohamed Sathak AJ College of Engineering, Chennai for providing necessary facilities to carry out the research work.

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