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# Quality characteristics and risk assessment of arsenic in drinking water of different Villages of District Sujawal, Sindh, Pakistan

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**Key words:** ADI, World health organization (WHO), pH, Arsenic kit method

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## Abstract

The purpose of present study was to create awareness on the effect of contaminated drinking water of Taluka Jati, Sindh, Pakistan and its adverse effects to local consumers. In order to attain this goal, total 35 water samples were collected randomly selected hand pumps and motor pumps of particular study area, in January 2017. The samples were analyzed and results were compared with the drinking water standards of the World Health Organization (WHO). The average arsenic contents found as (4.14g/L) in Mahdi Shah Farm, (15.34g/L) in Malhya Mori Stop, (12.74g/L) in Haji Qadir Bux Lodho, (3.34g/L) in Karim Dino Malhyo, (2.04g/L) in Haji Mir Muhammad Malhyo, (3.94g/L) in Mir Khan Stop, (7.74g/L) in Ibrahim Mandhro, (5.94g/L) in A. Qadir Malkani and (6.4g/L) was in Ghulam Shah Sim Nalo respectively. The arsenic mean ADI was also measured by standard method followed by reported formula. Safe arsenic daily intake in water was found as (0.66 g/day as (g/L). However, water samples of Malhya Mori Stop and Village Haji Qadir Bux. Lodho has maximum ADI of (0.828) and (0.682g/day) which shows that the people of these villages were at risk of various diseases such as skin lesions, black foot disease and various types of cancers etc. Physicochemical parameters of water samples of mentioned villages were also assessed that determines maximum values in villages Mahdi Shah Farm (Turbidity, Chlorides and Fluorides), Malhya Mori Stop (pH and Bicarbonate), Haji Qadir BuxLodho (opp), Karim Dino Malhyo (Alkalinity, Sulphate and Nitrate as N) and Ghulam Shah Sim Nalo (total hardness and electrical conductivity) as well.

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**Introduction**

Groundwater is extremely significant resource for both human consumption and agricultural purpose. Contaminated water may become health risk for all types of life because water is required for metabolism for all living organisms. For continuance of life on the earth, presence of adequate water quality is very important. Heavy metals may be considered as toxins to ecosystem, however their main source is believed as weathering of rocks and anthropogenic activities. Usage of safe and satisfactory supply of drinking water helps in inhibiting the spread of various diseases, improves the living standard, and cares domestic as well as personal health (Storelli, M. M., Storelli, A., D' Addabbo. 2005). Nowadays, groundwater is going to become contaminated due to human activities by continuously adding agricultural, domestic and industrial wastes to groundwater pools at frightening level. Similarly, quality as well as quantity of water is affected by adding a pollutant either physical or chemical alters the water quality by increase in anthropogenic activities. Human health could possibly be threatened by presence of chemical contaminants in drinking water all over the world. Since, it is very difficult to determine health effects of different contaminants, particularly, when investigating and learning the reactivity of the chemical in the body destroying cells and causing disease. Either chronic or acute health effects are caused due to toxic doses of contaminants.

Occasionally, high levels of chemicals are found in drinking water, which are responsible for acute health effects. However, chronic health effects are also found, which can occur by small quantities of toxic chemicals after long term exposure such as, damaged immune system, mottled teeth in children and chronic disorder of the nervous system. Arsenic is a metalloid and is toxic element and carcinogenic to human health its compounds (inorganic) are classified as Group-1, organic compounds are classified as Group 2B by International Agency for Research on Cancer. (Smedley, P. L. and Kinniburgh, D. G. 2002). Various types of cancers may be caused due arsenic exposure, for instance bladder, lung, liver and skin cancer and maybe the colon and kidney in developed countries, maximum permissible limit of arsenic in drinking water is followed as (10µg/L), while developing countries still follow the previous guideline value of 50µg/L because of unavailability of sophisticated instruments through which smaller concentrations may be analysed precisely.

Generally all villages situated at district Sujawal are present on lush ground. The land is very much appropriate for cultivation. It is having water supply through canals from Indus River. However, because of the poor supervision and less care of the Govt. of Sind the quality of drinking water is mostly fading up gradually and slowly. There are several sources of arsenic poison reported in the literature but the major sources in surface and ground water are industrial and farming contamination. Till now, no any detailed investigation using sophisticated instruments has been carried out for drinking water quality in Sujawal district by any government or national agency which may be trusted for its quality. As a result, the arsenic investigation in ground water of this study area was very much necessary so as to aware the people of this region to combat the hidden enemy inside their drinking water. It is worth to mention here that the people of this area wer suffering from strange and not curable diseases might be due to arsenic exposure. The aim of this study was to locate the actual concentration of arsenic in ground or public intake water of this area and to distinguishthe likely pollution sources with the help of statistical and geochemical data. The samples from many sites of Sujawal district have been collected and analyzed for the arsenic hunt using hydride generator system coupled with atoimic absorption spectrophotometer.

Previously different areas of Sindh were focused by many researchers regarding the quality of drinking water which is mainly ground water resources. Different cities of Sindh shown life threatening levels of arsenic which is poisonous element in trace levels. In this context particular area drinking water was analysed to ensure the levels of different element levels to aware consumers and different water management authority to solve health risk problems.

It is the responsibility of government to produce safe and potable water to the people of Taluka Jati which is found mostly unavailable. Communities of the Taluka Jati depend upon groundwater sources, whereas quality of the groundwater is not satisfactory because of health risks to users who depend on this source as drinking purpose. The aim of present study is to assess the arsenic concentration and physicochemical parameters such as pH, TH, TDS, EC, Alkalinity, Turbidity, Chlorides, Sulphates, Bicarbonates, Fluorides, Nitrate as Nitrogen and orthophosphate phosphorus in the groundwater of Taluka Jati. (WHO, 2011). This is important because recently number of cases were reported such as; skin lesions, black foot diseases, stomach cancers, cardiovascular, kidney failure, liver damage, cancer, gastrointestinal irritation blue baby disease, abdominal pain, renal damage, depression and hypertension in people living in study area.

## Material and methods

*Description of Study Area*

Jati is one of the Talukas of Sujawal District; coordinates of the district are 24°36'23" of North and 68°4'19" of East. It is bordered in the northeast by Indus River. According to census of 2017, Population of Taluka Jati is 202,299. The climate of study area is dry tropical and is under the influence of monsoon. The average annual rainfall on the study area is 220 mm. The temperatures range between 23.8 and 28.7°C for study area.

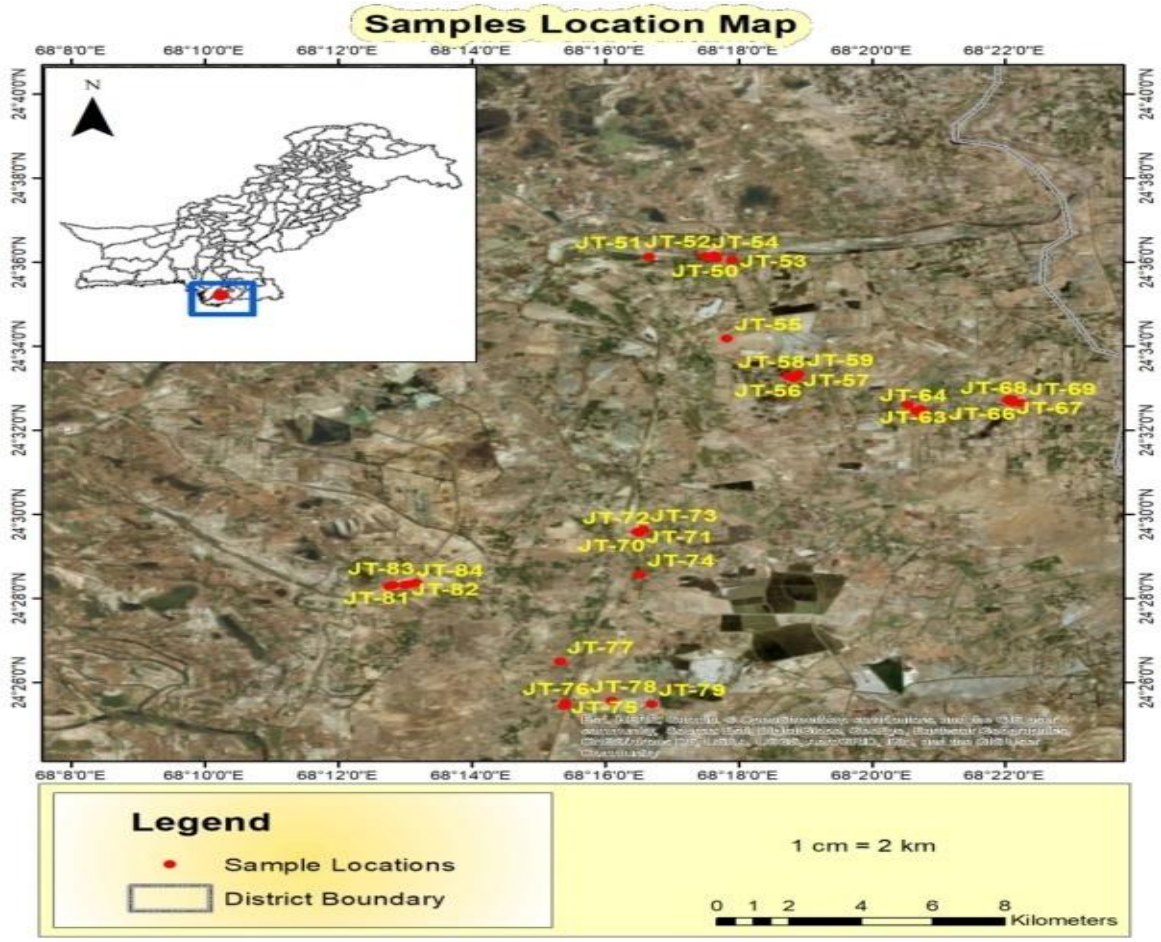


**Fig. 1.** Map of sampling points from coastal area of Taluka Jati.

*Samples Collection*

All samples of drinking water were collected in triplicate from each location in which different water sources were fitted by villagers. Usually hand pumps and motor pumps were fitted by villagers to get groundwater for drinking, cooking and washing purposes. Ground water source was run for 2-5 minutes till fresh water.

The depth of water sources was found 15-35 feet in different villages of study area. Some selected villages/areas from water sampling was carried out included Mahdi Shah Farm, Malhya Mori Stop, Haji Qadir Bux Lodho, Karim Dino Malhyo, Haji Mir Mohammad Mandhro, Mir Khan Stop, Ibrahim Mandhro, A. Qadir Malkani and Ghulam Shah Sim Nalo. GPS was used to record the DMS coordinates of sampling points for authenticity of results (Table. 3). In total 35 samples of drinking water were collected in 1.5 L capacity of plastic bottles from Taluka Jati of Coastal Area of Sindh. During sample collection pH and EC were measured in the field.

*Chemicals and Reagents*

All chemicals used were of A.R grade reagent and purchased from Merck and Fluka. Standard solutions were prepared from chemicals with de-ionized water for required range of concentration for calibrating the instrument and to measure concentration of different parameters from water samples.

*Samples Analysis*

Sample analysis was carried out by classical and automated instrumental techniques described by standard methods for water and waste water as well as United State Environmental Agency (USEPA). UV-Vis Double Beam Spectrophotometer (CECIL 9500) was used to determine the concentration of major ions such as, fluorides (SPANSA method), nitrate-nitrogen (Bruccine Sulfanalic acid method), *o*-phosphate-phosphorus (ammonium molybdate and ascorbic acid method) and sulphates (gravimetric method). The Ph and EC were measured on the sampling spot.( NAPAM. 2007). The pH was measured with the help of pH-meter, which was calibrated by standard buffer solutions with pH of 4.0 and 10.0. The EC, TDS and turbidity were analysed by HANNA Instruments Conductivity meter. Alkalinity by neutralization , chlorides ($Cl^-$) by estimated by Argentometric method mentioned in APHA (2005), total hardness of samples was determined by EDTA titrimetric method depicted in APHA (2005).

**Results and discussion**

*Human Health Risk Assessment of Arsenic*

The WHO standard limit of arsenic for drinking water is recommended as (10µg/L), however results of different villages of Taluka Jati show that Average arsenic content of (15.37 µg/L) and (12.70µg/L) was determined in villages Malhya Mori Stop and Haji Qadir Bux Lodho respectively. In drinking water samples of these villages total arsenic intake of (0.82µg/L) and (0.68µg/L) was found. ADI shows the average arsenic content in groundwater multiplied by daily consumption of water divided by body weight.

**Table 1.** Arsenic daily intake from groundwater of different villages of Taluka Jati.

| Villages | M.S.F | M.M.S | H.Q.B.L | K.D.M | H.M.M.M | M.K.S | I.M | A.Q.M | G.S.S.N |
|---|---|---|---|---|---|---|---|---|---|
| As Mean (µg/L) | 4.154 | 15.37 | 12.7 | 3.38 | 2.0 | 3.925 | 7.786 | 5.96 | 6.434 |
| ADI | 0.224 | 0.828 | 0.684 | 0.182 | 0.108 | 0.211 | 0.419 | 0.321 | 0.346 |

Note: Safe level of arsenic daily intake in water is (0.66µg/day) as (µg/L).

The daily water consumption as well as normal body weight was supposed mean as (3.0-3.5L) and 65kg respectively. The (Table 1) shows the data of ADI values. It was found that villages Mahdi Shah farm, Karim Dino Malhyo, Haji Mir Mohammad Mandhro, Mir Khan Stop, Ibrahim Mandhro, A. Qadir Malkani and Ghulam Shah Sim Nalo displays ADI values within safer limits of (0.66µg/day).

It was found that accumulation of As in body was observed within safe level in seven villages out of nine. However, people of seven villages of Taluka Jati are much safer than other parts of the country.

Since the people of villages Malhya Mori Stop and Haji Qadir Bux Lodho are found at greater risk of arsenic contamination due to higher ADI values (Table 1).Various problems such as, bladder cancer, lungs cancer, skin lesions, diabetes, cardiovascular disease, hypertension, black foot disease and keratosis may be caused in future by consuming arsenic contaminated drinking water in mentioned villages. The ADI values when compared with each other showed that the village Ibrahim Mandhro had higher value of (0.419µg/L), while the lowest ADI of 0.108µg/L was found in village Mir Muhammad Mandhro.

The pH is defined as negative logarithm of the hydrogen ion concentration [$H^+$] of a solution, which measures whether a solution is acidic or basic. The pH of all samples was found within safe limit of (6.5-8.5) given by WHO water quality guidelines, whereas maximum and minimum average range was measured as (7.2-7.4) in all water samples of villages under study of Taluka Jati (Table 2).

The contamination of hardness more than (500mg/L) in water has adverse effects on human health and may cause heart disease and formation of kidney stones. The mean concentration of TH was found within safe limits in drinking water of villages Haji Qadir Bux Lodho, Haji Mir Muhammad Mandhro, Mir Khan Stop and Abdul Qadir Malkani. Water samples of villages Mahdi Shah Farm, Karim Dino Malhyo, Ibrahim Mandhro and Ghulam Shah Sim Nalo declared alarming concentration of total hardness (Table 2).

**Table 2.** Average levels of physicochemical Parameters in water samples of different villages of Taluka Jati, District Sujawal, Sindh.

| | WHO Limit | M.S.F | M.M.S | H.Q.B.L | K.D.M | H.M.M.M | M.K.S | I.M | A.Q.M | G.S.S.N |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 6.5 - 8.5 | 7.18 | 7.4 | 7.3 | 7.36 | 7.3 | 7.35 | 7.3 | 7.36 | 7.36 |
| TH | 300 mg/L | 425.6 | 421 | 231.25 | 446.8 | 233 | 277 | 521.2 | 164.6 | 530.4 |
| TDS | 1000mg/L | 1492 | 1113 | 1167.75 | 1456.6 | 1087 | 1130 | 1774.2 | 1082.8 | 1877 |
| EC | NL (µg/L) | 2227 | 1661 | 1742.75 | 2174.2 | 1622 | 1687 | 2648 | 1616.2 | 2801.4 |
| Alk | NL (mg/L) | 346.1 | 336 | 385.36 | 432.78 | 336 | 340 | 416.11 | 389.447 | 403.38 |
| TURB: | 5 NTU | 3.152 | 1.1 | 1.2175 | 1.294 | 1.5 | 1.408 | 1.67 | 2.62 | 2.202 |
| $Cl^{-1}$ | 250 mg/L | 463 | 338 | 320.75 | 401.2 | 338 | 340.2 | 356.4 | 311.2 | 339 |
| Sulf | 250 mg/L | 170 | 54 | 88.75 | 134.8 | 100 | 114.5 | 192.8 | 57.4 | 188.6 |
| Bicarb | NL (mg/L) | 250.4 | 323 | 251.75 | 201 | 230 | 271.2 | 226.6 | 315.8 | 212 |
| $F^{-1}$ | 1.5 mg/L | 0.192 | 0.187 | 0.1575 | 0.148 | 0.18 | 0.142 | 0.144 | 0.134 | 0.1232 |
| Nitrate as N | 10 mg/L | 1.114 | 0.74 | 1.13 | 1.558 | 0.67 | 0.715 | 0.788 | 0.346 | 0.97 |
| o-p-p | NL (mg/L) | 0.0394 | 0.03 | 0.0466 | 0.0376 | 0.041 | 0.041 | 0.0255 | 0.0280 | 0.0235 |

NL = Not Listed, o-p-p = orthophosphate phosphorus, alk = alkalinity, TURB: = Turbidity, Bicarb = bicarbonate,

For Total Dissolved Solids the term Total Filterable Solids sometimes employed. This parameter is measured as for total solids excluding that the sample is filtered via a clear medium formerly. The TDS content in all water samples of selected villages was found with higher concentration as recommended by WHO guidelines; however average minimum and average maximum TDS content of (1087mg/L) and (1877mg/L) was observed in water samples of Haji Mir Muhammad Mandhro and Ghulam Shah Sim Nalo respectively (Table 2).

Electrical Conductivity (EC) is described as the ability of water to conduct current. The average value of electrical conductivity was measured in all selected villages of Taluka Jati which showed the lowest average level (1616.2µS/cm) in village abdul Qadir Malkani and the highest level of (2801.4µS/cm) in village Ghulam Shah Sim Nalo (Table 2). Hydrogen ions or acids in water may be neutralized by alkalinity, which is occasionally known as “Carbonate hardness”. Safe drinking water must have high content of alkalinity ranging from (20-200mg/L). The average alkalinity level was measured from villages under study which showed the highest content of (432.78mg/L) in village Karim Dino Malhyo and the lowest alkalinity of 336mg/L in Villages Malhya Mori Stop and Haji Mir Muhammad Mandhro (Table 2). Very finely divided solids are responsible for turbidity in water. Water becomes unacceptable if turbidity is present in water above than permissible level. Utility of turbid water is also affected in industries. Water treatment is also affected by turbidity and disadvantages could be serious in the process of disinfection. In water turbidity is caused due to sewage matter shielding pathogenic organisms by which action of disinfectant can be escaped. Minimum and maximum turbidity level of (1.1) and (3.1) NTU was measured from groundwater of villages Malhya Mori Stop and Mahdi Shah Farm respectively.

The average turbidity of groundwater of all villages under study displayed safe level of 1.5 NTU recommended by WHO (Table 2).

The average chloride content was measured in groundwater samples of selected villages of Taluka Jati. Analytical results showed the upper and lower limit of (463mg/L) and (311.2mg/L) in samples of village Mahdi Shah Farm and Village A .Qadir Malkani respectively, which was found higher as compared to recommended level of 250 mg/L by WHO (Table 2). By presence of sodium and magnesium in water, laxative effect is observed when combine with sulphate. Therefore water containing high level of sulphate (>250mg/L) may be carefully used for domestic purpose.

The average sulphate content of (188.6 mg/L) was observed as maximum in groundwater of village Ghulam Shah Sim Nalo and average minimum sulphate level of 54mg/L was found in village Malhya Mori Stop (Table 2). Bicarbonate is most plentiful anionic species present in stream water and plays an important role in conductance of water. It is strongly correlated with various important ions particularly with calcium cation. The WHO, EPA, China and Canada have not mentioned the drinking water quality standard for $HCO_3^{-1}$.

The average bicarbonate highest level of (323mg/L) was displayed by groundwater samples of village Malhya Mori Stop, whereas the average lowest level of 201mg/L was determined in groundwater of village Karim Dino Malhyo. The closer bicarbonate contents of 250.4mg/L and 251.75mg/L were measured in groundwater samples of villages Mahdi Shah Farm and Haji Qadir Bux Lodho respectively (Table 2).

Concentration of $F^-$ greater than 1.5mg/L in drinking water possesses severe health effects as well as teeth mottling arises. Therefore, there is restriction on the level of $F^-$ which is changed with change in temperature. The maximum average fluoride content of 0.192mg/L was found in the groundwater of Mahdi Shah Farm while the minimum content of 0.1232mg/L was observed in the village Ghulam Shah Sim Nalo. The equivalent fluoride contents of 0.142mg/L and 0.144 mg/L were determined in water samples of villages Mir Khan Stop and Ibrahim Mandhro respectively (Table 2). The higher and lower average levels of Orthophosphate phosphorus were found as (0.046mg/L) and (0.02mg/L) in groundwater of villages Haji Qadir Bux Lodho and Ghulam Shah Sim Nalo respectively. The identical level of 0.041mg/L was measured in the groundwater of Haji Mir Muhammad Mandhro and Mir Khan Stop respectively (Table 2).

**Table 3.** Correlation of arsenic in drinking water of selected villages of Taluka Jati.

| | M.S.F | M.M.S | H.Q.B.L | KD.M | H.M.M.M | M.K.S | I.M | A.Q.M | G.S.S.N |
|---|---|---|---|---|---|---|---|---|---|
| M.S.F | 1 | | | | | | | | |
| M.M.S | 0.427 | 1 | | | | | | | |
| H.Q.B.L | -0.605 | 0.41 | 1 | | | | | | |
| KD.M | 0.254 | -0.316 | -0.623 | 1 | | | | | |
| H.M.M.M | 0.427 | 1.000** | 0.41 | -0.316 | 1 | | | | |
| M.K.S | -0.028 | 0.643 | 0.45 | -0.647 | 0.643 | 1 | | | |
| I.M | 0.433 | -0.126 | -0.703 | 0.934* | -0.126 | -0.371 | 1 | | |
| A.Q.M | -0.642 | -0.225 | 0.555 | 0.106 | -0.225 | -0.468 | -0.216 | 1 | |
| G.S.S.N | 0.336 | -0.627 | -.899* | 0.825 | -0.627 | -0.749 | 0.762 | -0.144 | 1 |

**Correlation is significant at the 0.01 level (2-tailed).*.

*Correlation coefficient of arsenic*

The strongest positive correlation of 1.0 of arsenic was observed between groundwater of villages Haji Mir Muhammad Mnadhro and Malhya Mori Stop at the significant level of (0.01). This may indicate the similar source of arsenic contamination of groundwater of these villages. Similarly, groundwater of village Ibrahim Mandhro and village Karim Dino Malhyo also displayed the strong positive correlation of (0.93) at the significant level of 0.05.

The strong negative correlation of (-0.89) was also observed between the groundwater samples of village Ghulam Shah Sim Nalo and village Haji Qadir Bux Lodho at the significant level of (0.05) (Table 3).

**Conclusion**

From the present study it may be concluded that arsenic concentration was found in higher level in villages Malhya Mori Stop and Haji Qadir Bux Lodho against WHO recommended level of 10µg/L. However, risk assessment of arsenic was also observed in these two villages which may cause serious health problems. The levels of pH, turbidity, sulphate and nitrate-nitrogen were found within safe limit in groundwater of all the selected villages. Maximum contaminant levels of EC, Alkalinity, and bicarbonate and orthophosphate phosphorus are not listed for drinking water. The mean chloride and TDS concentration were observed greater than WHO level of 250mg/L and 1000mg/L respectively in groundwater of all the selected villages.

Total hardness of groundwater of villages Mahdi Shah Farm, Malhya Mori Stop, Karim Dino Malhyo, Ibrahim Mandhro and Ghulam Shah Sim Nalo were found higher than WHO limit 300mg/L. In the groundwater of the rest of villages total hardness was below the mentioned limit.

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**Disclosure statement**

No potential conflict of interest was reported by authors.

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