Water Quality Assessment of the Cutuchi River Basin (Ecuador): A Review of Technical Documents

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Abstract. The Cutuchi River Basin extends over the inter-Andean valley south of the Cotopaxi Volcano, in Ecuador. It flows through two provinces, Cotopaxi and Tungurahua, and its waters are extensively used to irrigate crops that provide food to the main cities in the country. Unfortunately, the basin receives untreated domestic and industrial discharges. The need for an environmental quality assessment of the river has been acknowledged over the years. The aim of this study is to gather information about water quality of the Cutuchi River through a historical bibliographic review. A total of 57 works published between 2007 and 2018 were found, including books, articles, thesis and project reports. Only 18 documents provided biological, physical, or chemical data linked to water quality. The data obtained through the literature review were compared with maximum thresholds from national and international regulations. Unfortunately, revised studies were scattered on time and randomly along the basin and did not provide robust information to evaluate the state of the water-system. Some contamination was detected significantly exceeding safety thresholds. More exhaustive studies along the basin are needed as a baseline to help the decision makers to design management plans and mitigate human impacts.

1. Introduction

Water quality degradation endangers aquatic ecosystems, affects human health, and hinders social and economic development [1]. More than 70% of domestic and industrial wastewater is discharged into rivers without any treatment, representing one of the biggest sources of environmental pollution, mainly in developing countries [2, 3]. Ecuador has a high-water availability (around 28,110 m³ per person per year), more than the average in Latin America (22,000 m³ per person per year) [4]. According to the Food and Agriculture Organization of the United Nations [5], total water extraction in Ecuador was 16,985 million m³/year, and 13,929 million m³/year (82%) were used for agriculture. Furthermore, water is a source in risk in Ecuador because only 7% of the domestic and industrial wastewater is treated before being released into the rivers [6].

The Cutuchi River Basin extends over the inter-Andean valley south of the Cotopaxi Volcano, in central Ecuador. The population on the area is over 300,000 inhabitants. Most of them are found on “La Gran Latacunga” conurbation, integrated by Latacunga, Salcedo, Pujílì y Saquisílì cities and their surrounding settlements, summing up to 298,440 inhabitants [7]. Due to the high population density, the basin receives a significant flow of untreated domestic and industrial discharges. The estimated sewage is around 30,000 m³/day, it goes directly to the river and represents a 3.6% of its mean flow [8]. The
river also receives waste waters from at least 88 companies related to agriculture (57%), industries (16%), oil-related (23%) and others (4%). Besides the sewage, Cutuchi River gets no less than 1.8 tons of trash per day [9].

This situation is especially worrisome because the water of Cutuchi River Basin feeds Latacunga-Salcedo-Ambato canal, used for irrigation of more than 24,000 ha of cropland [10]. The food produced using this polluted water exposes consumers to a high health risk due to the accumulation of toxic compounds [11] and microbial infections [12]. This water pollution not only affects the population of Cotopaxi and Tungurahua Provinces, but also the two largest cities of the country, Quito and Guayaquil, where much of this agricultural production is consumed [13].

The aim of this study is to assess the water quality of the Cutuchi River through a historical bibliographic review of all the published technical documents.

2. Methods

2.1. Study Area and Data

Cutuchi River flows 91.74 km north to south, from its source on the Cotopaxi Volcano on Central Ecuador at 4,004 m asl, to the confluence with Ambato River at 2,240 m asl [14] (Figure 1). It belongs to the upper basin of the Pastaza River, one of the main rivers of the Ecuadorian Amazon. Over its course, it goes through several small towns and the capital of the Cotopaxi Province, Latacunga, to the capital of Tungurahua Province, Ambato, where it is renamed Patate after meeting Ambato River. The Basin has an approximate area of 428,020.87 ha [15] and a population of approximately 300,000 inhabitants [7]. The average annual flow between 1990-2014 (25-year records) was 9.64 m$^3$/s. The flood season occurs from February to June, with an average peak flow of 15.61 m$^3$/s recorded on May, while the low water season goes from July to January, with an average minimum flow of 5.61 m$^3$/s recorded on August [16].

During September 2019, we gathered studies of Cutuchi River Basin from repositories of Ecuadorian universities and Google Scholar. We selected the works with water quality analysis data. We consulted the Ecuadorian norm for irrigation water quality (including 27 parameters) [17] and the guidelines of the United States Environmental Protection Agency (EPA) (including 17 parameters) [18] (Table 2). Both norms used similar thresholds for considering the water safe for irrigation. The Ecuadorian norm was more restrictive, except for pH (wider permissible range for Ecuador), boron and cadmium (slightly lower threshold for the EPA). Sampling points from the studies were located on the map using QGis [19] (Figure 1).
Figure 1. Cutuchi River Basin map and sampling sites from selected studies. Most of the sites were located in Latacunga and appear overlapped on the figure.

3. Results and Discussion

We found a total of 57 documents published between 2007 and 2018: bachelor’s thesis (35), master’s thesis (11), papers (7), books (2) and project reports (2). From the reviewed works, 26 of them were not directly related to water quality evaluation; four were related to water quality but did not have any data; nine were related to water quality on the Cutuchi Basin but presented data of specific industrial spills. Only 18 documents included information about water quality on the Cutuchi River Basin (Table 1). Of them, 11 reports analyzed water quality on the Cutuchi River, four papers presented data for tributaries and three were carried out on the Lasso-Latacunga-Salcedo irrigation canal. From those documents, 13 were bachelor’s theses and five were master’s theses. These 18 theses were selected for the analysis.

Table 1. References of the papers distributed along the basin, on the Cutuchi River, tributaries or irrigation canal; references of bachelor’s and master’s theses; and number of sampling sites and references of the evaluated documents.

| Location            | Number of papers | Reference                        |
|---------------------|------------------|----------------------------------|
| Cutuchi River       | 11               | [20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30] |
| Tributaries         | 4                | [31, 32, 33, 34]                  |
| Irrigation canal    | 3                | [35, 36, 37]                      |

* do not include precise coordinates
Based on the data obtained from the aforementioned research, we identified 32 surveyed points located on the map (Figure 1). Five studies lacked precise coordinates (Table 1) and were not included on the figure, although their data are shown on Table 2. One of the studies had eight sampling points, the highest number reported; two documents presented data for six sites; three of them had five sites; six studies had three samples; the rest of the theses considered two or one site (Table 1). We gathered data for 25 physical, chemical, and biological parameters. From those parameters, 16 are considered on the Ecuadorian norm for irrigation water quality evaluation (from a total of 27 parameters listed on the national law) and were used for the diagnosis (Table 2). Only four parameters were repeated on five or more works: pH (13), total fecal coliforms (7), nitrates (5) and dissolved oxygen (5), while the rest were present on three or less papers.

Table 2. Summary of the parameters from the 18 selected documents. For studies with more than one sampling site the mean value and the maximum value are shown. Includes thresholds for the legally considered parameters for irrigation water quality evaluation from Ecuadorian norm [17] and United States Environmental Protection Agency norm (EPA) [18]. Numbers in bold show values above the most conservative norm for each parameter. Source indicates reference paper.

| Parameter       | ECUADOR | EPA | Max | Mean | Source | Parameter       | ECUADOR | EPA | Max | Mean | Source |
|-----------------|---------|-----|-----|------|--------|-----------------|---------|-----|-----|------|--------|
| Oil and Grease  | Absent  | ---- | Present | Present | [20] | Sulphates (mg/l) | 250    | ---- | 102.8 | 22.95 | [23]  |
| Fecal coliforms | 1000    | ---- | 2395 | 2395 | [23] | pH             | 6.0-9.0 | 6.5-8.4 | 8.9 | 8.3 | [20]  |
|                 | High    | 3,200,000 | High | 3,200,000 | 31 | |                  | 7.7 | 7.7 | 7.2 | [21] |     |
|                 | 70      | 70   | 32  | 37   | [37] |                 | 7.4 | 7.4 | 7.2 | [23] |     |
|                 | 35,000  | 35,000 | 33  | 37   | [37] |                 | 9.4 | 9.1 | 9.2 | [25] |     |
|                 | 400,000 | 400,000 | 35  | 37   | [37] |                 | 8.2 | 7.9 | 7.9 | [27] |     |
|                 | 730,000 | 92,000 | 37  | 37   | [37] |                 | 7.9 | 7.9 | 7.9 | [29] |     |
| Zinc (mg/l)     | 2       | 2    | 0.21 | 0.19 | [20] |                 | 8.2 | 8.0 | 8.0 | [30] |     |
| Chromium (mg/l) | 0.1     | 0.1  | 0.7 | 0.9 | [32] |                 | 8.2 | 7.9 | 7.9 | [33] |     |
|                 | <0.5    | <0.5 | <0.5 | [30] |   |                 | 8.2 | 8.1 | 8.1 | [34] |     |
|                 | <0.025  | <0.025 | <0.025 | <0.025 | 33 | | 8 | 7.8 | 7.8 | [37] |     |
| Dissolved oxygen (mg/l) | 3* | ---- | 0.1 | 6.3 | [24] | Nitrates (mg/l) | 0.5 | 10.1 | 9.5 | [20] |     |
|                 | <1     | 2.8 | [26] |     |     |                 | 3.1 | 3.1 | 3.1 | [23] |     |
|                 | 6.7    | 6.7 | [31] |     |     |                 | 0.8 | 0.8 | 0.8 | [24] |     |
|                 | 8.6    | 8.6 | [32] |     |     |                 | 4.9 | 2.5 | 2.5 | [28] |     |
|                 | 3.6    | 4.6 | [34] |     |     |                 | 1.5 | 1.5 | 1.5 | [35] |     |
From the 18 studies analyzed, one reported presence of oil and grease [20]; total fecal coliforms extensively exceeded the threshold on six studies and eight sites [23, 28, 31, 33, 35, 37]; very high levels of chromium were reported by one of the papers for five sites [22], and for other study the analytical sensitivity of the methods concealed the evaluation [30]. Metrics for dissolved oxygen were below the limits in seven sampling sites (five sites [24] and two sites [26]). In five sites, pH values were above the upper threshold of the EPA norm (two sites [20] not exceeding the Ecuadorian norm limits, and three sites [25] exceeding both norms). One site surpassed the less restrictive EPA limit for nitrates and nitrites concentration [20] although all the studies reported concentrations over the Ecuadorian norm [20, 23, 24, 28, 35]. Cadmium concentration was high above the threshold on five sites as reported by one of the documents [22]. Three sites in one study [33] exceeded boron limits for the EPA norm but not the Ecuadorian legislation. The rest of the studies and sampling sites did not register any value out of the limits stablished by the Ecuadorian irrigation water quality legislation nor the EPA norms.

Taking these results in consideration, we believe that the available bibliography is insufficient to evaluate the water quality of the Cutuchi River Basin. Although we found many studies focused on this water system, few of them reported useful data to our purpose. Moreover, none of the studies on water quality evaluation were peer reviewed documents, thus we could not rely on them for a precise and robust evaluation. Furthermore, the long-time span (2007-2018), the randomly distributed sampling sites and the scattered and insufficient parameters evaluated, highlight the significant information gaps involving the water quality monitoring on the Cutuchi River Basin. Nevertheless, some data stand out and reveal high levels of pollution, something obvious considering all the untreated industrial and domestic sewage that a small river like Cutuchi endures daily. A recently published research proves this statement reporting critical values for Cr, Cd, Pb, As and Hg, warning about a high health risk for the people using this water and consuming the food irrigated with it [38].

4. Recommendations

With the available information we cannot evaluate the water quality of Cutuchi River Basin. On the light of recent studies and with the huge information gaps reported through this work, we recommend some critical actions to properly assess water quality and improve management on the basin. More exhaustive studies on environmental quality along the river system are needed to create a consistent baseline and help decision makers design adequate management plans. Also, there is a need of standardization of the information gathered by different studies, including adequate geographic coordinates, equivalent techniques and solid parameters guided by the Ecuadorian water quality norm. A long term and robust monitoring program should be implemented by the local government to evaluate water quality on the basin and specially on irrigation water canals. Finally, it is evident that if we aim for a mitigation and restoration on the Cutuchi River system, sewer and industrial wastewater needs to be treated before getting into the river. An urgent water treatment plan should be carefully designed and implemented, along with an extensive ecological restoration strategy that may facilitate the improvement of water quality on the Cutuchi River Basin.

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