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Social perception about the reuse of recycled water in VRAEM agriculture. Inclusion of the social dimension in Kimbiri-Sampantuari (Cusco)

Rita J. Cabello-Torres, Ms[1], Alexei Cavero Ledesma[1], Carlos A. Castañeda Olivera, DSc[1], Freddy Pillpa Aliaga, Ms[1], Edison A. Romero-Cabello[2], Lorgio Valdiviezo Gonzales, DSc[3]
[1,3]Escuela de Ingeniería Ambiental, Universidad César Vallejo, Lima, Perú, rcabello@ucv.edu.pe, caralcaso@gmail.com
[2]Universidad Nacional Agraria La Molina, Lima, Perú, ediromero2000@gmail.com
[3]Universidad Tecnológica del Perú, UTP, campus de San Juan de Lurigancho, Lima, Perú, *lvaldiviez@utp.edu.pe*

Abstract*–The reuse of recycled water in agricultural activities requires integrated management to strengthen a greater perception of citizen acceptance and guarantee the sustainability of its use. The perception of risk and acceptance of the farmers of Sampantuari-Kimbiri (Cusco) regarding the reuse of recycled water was analyzed through a survey carried out in the community and a bibliographic review directly related to the WWTP project. The results revealed a lack of knowledge about the benefits of reuse and therefore a high perception of risk in the quality of the effluent, sanitary conditions, but considered its use in crops acceptable. The municipality of Kimbiri and independent actors such as the university must strengthen alliances to improve the availability of information, raise the level of awareness, knowledge and acceptance for its reuse in agriculture; within the framework of sustainable development in the integrated management and circular economy of water.
Keywords—reuse of recycled water, risk and acceptance, agriculture, native community and settlers

Resumen—La reutilización de agua reciclada en actividades agrícolas requiere de una gestión integrada para fortalecer una mayor percepción de aceptación ciudadana y garantizar la sostenibilidad de su uso. Se analizó la percepción de riesgo y aceptación de los agricultores de Sampantuari-Kimbiri (Cusco) respecto a la reutilización de agua reciclada mediante una encuesta realizada en la comunidad y una revisión bibliográfica relacionada directamente con el proyecto de PTAR. Los resultados revelaron un desconocimiento sobre los beneficios del reúso y por ende una alta percepción de riesgo en la calidad del efluente, condiciones sanitarias, pero consideraron aceptable su uso en cultivos. El municipio de Kimbiri y actores independientes como la universidad deben fortalecer alianzas para mejorar la disponibilidad de información, elevar el nivel de conciencia, conocimiento y aceptación para su reutilización en la agricultura; en el marco del desarrollo sostenible en la gestión integrada y economía circular del agua.
Palabras clave—reutilización de agua reciclada, riesgo y aceptación, agricultura, comunidad nativa y colonos

I. Introduction

The lack of adequate and safe water for human development is one of the greatest threats that will be faced in the next century, it is expected that half of the world's population will live in conditions of water scarcity by the year 2030, given the current scenarios climate change [1]; including the groundwater crisis [2].

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Ensuring a sufficient water supply for humans is a constant challenge in many parts of the world; as population growth and increased urbanization will exacerbate water security issues in the future [3]. Generally, the availability of water masses from different natural water sources has been taken advantage of, whose storage or purification allow the development of activities normally during brief periods of drought and have provided water security in the last century [4].

An important solution to current and future water scarcity is to augment existing supplies with unconventional water sources [5]. Recycled water is an effective way to alleviate the scarcity of regional water resources and promote environmental protection [3]. This makes wastewater an alternative source, more stable and available than rainwater, which depends on precipitation [6]. In this case, the production of recycled water must ensure its quality and quantity, it must eliminate the contaminants present by improving its process or treatment, its accessibility and long-distance transfer; not only the production costs must be evaluated and compared with other engineering solutions; even though recycled water is more environmentally friendly [7].

In contrast, wastewater recycling and reuse planning often stalls; due to lack of public acceptance [8], as a result of the general perception of risk. The acceptance of the community plays a crucial role in the implementation projects of alternative water systems, since the attitude of the public is influenced by the perception of health risk, by their religion, politics and socio-cultural aspects; especially in developing countries [7].

There is engineering research focused on the innovation technologies, which drive investments for wastewater treatment [9], but if the social perception of its reuse is not investigated; there is a risk of not being accepted by the community. The direct user population of recycled water represents a key link to crystallize implementation projects for treatment and reuse, due to their attitudes of acceptance or rejection [7]. The need to have an independent advisory panel, which acts in a transparent manner, has also been recommended, in this way the concern of the public could be counteracted, knowing that someone trained can ask the authorities the difficult questions and in the same way share the findings with the community [4].

In this context, the university has a crucial role not only in engineering practices but also socially, its academic participation and approach to the community can help raise awareness, explain the emerging risks, benefits and costs of reuse in human health and environmental [2]. Cesar Vallejo University manages the gender, social inclusion and cultural diversity approach, linked to objective 6 of the United Nations Organization on sustainable development in terms of clean water and sanitation, especially in the most vulnerable communities. In the professional career of environmental engineering, not only water purification or wastewater treatment technologies are investigated, among other subjects; values, justice and social inclusion are instilled in young university students as one of the crucial components that must be part of engineering projects. In this context, an approach was initiated to the Sampantuari community of the Kimbiri district, with the aim of investigating the perception of the reuse of recycled water in the population made up of Asháninca indigenous people and residents of Sampantuari in the VRAEM Cusco (Perú).

I. METHODOLOGY

A. Study area and water supply in the Kimbiri district (Cusco)

Kimbiri is a district of the province of La Convención in the Cusco Region (Perú), located at coordinates 12°30'42” south and 75°51'30” west and at an altitude of 500 m.a.s.l.; which is part of the emergency zone of the Valley of the Apurímac and Ene rivers (VRAEM). (See Figure 1).

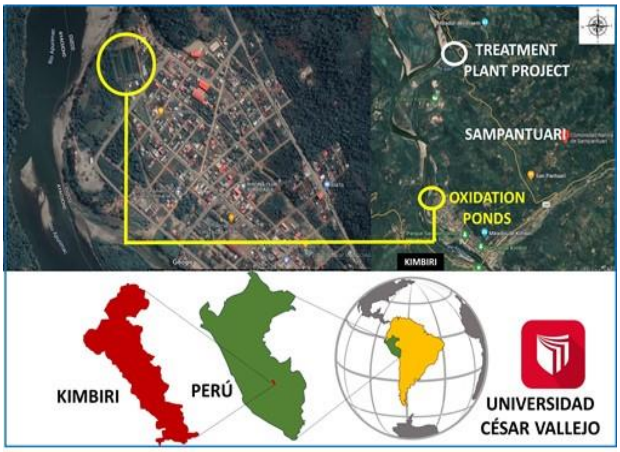

Fig. 1. Project site in Kimbiri (Cusco)

According to the 2017 National Census [10] this district is made up of 5,913 inhabitants and 2,040 homes, it maintains an accelerated population growth in the lower part, where Sampantuari and new population centers are located. The 2022-2024 Operational Plan of the municipality of Kimbiri considers improving and expanding the coverage of the basic services of the drinking water and sewage system by 95% (Mayor's Resolution 87-2022-MDK/A)[11] and has contemplated developing a domestic wastewater treatment plant, since it only has 4 primary treatment oxidation lagoons. The municipality of Kimbiri is in charge of supplying drinking water. The Kashiroveni River is the surface source that supplies the catchment system, it works by gravity, it has a fixed dam channel and a diversion channel. The purification process is carried out in the drinking water treatment plant (DWTP), for this, the liquid flow enters a meeting box (pressure rupture chamber) and copper sulfate is applied as a coagulant. The plant has a central reservoir of 6,750 m³, Parshall throat gutter, flocculation, decanting and rapid filtration units [12] (see Figure 2). In the disinfection section, gaseous chlorine is applied directly to the main tank of 650 m³ capacity. In addition, the city only has a sewage system, made up of the public network inside and outside the home (interior of the building), a cesspool and some canal, managing to cover only 30% of the population. The wastewater feeds four oxidation ponds, after the process, the effluent is discharged into the Apurímac River, however, illegal discharges into the river have also been detected, which causes contamination of the water resource.

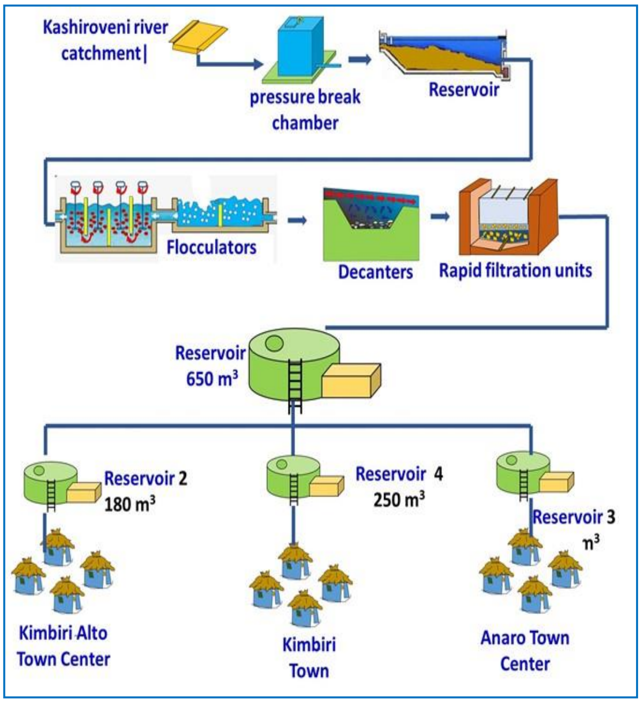

Fig. 2. Drinking water supply system

B. Brief analysis on the perception and acceptance of wastewater reuse by farmers

The literature shows the different public perceptions about the reuse of treated wastewater. The risks that could threaten health have been highlighted, farmers focus their decision on accepting or rejecting the reuse of this treated wastewater based on aquatic quality standards [13]. In the city of Apulia (Italy), a high level of acceptance was shown in the reuse of this recovered water, in which public opinion stood out (87%), compared to that of farmers (59%), because most farmers do not always prefer it, although they are willing to take advantage of its benefits from time to time; and this criterion in turn has its origin in the negative perception of health risks, which would cause diseases due to the presence of toxic chemical substances[14].

Contradictions have also been pointed out in the attitude of farmers, who despite showing their rejection of its reuse for irrigation, based on environmental and health risks, dismiss the rigors of aquatic quality standards related to food safety, when the availability of water resources is not assured [13]. Furthermore, Ricart, Rico, and Ribas (2019) demonstrated how farmers' willingness to reuse this water to irrigate their crops decreased over the years due to proven effects on soil and food productivity [15]. It has also been suggested that public acceptance related to the reuse of these waters for food production depends on the interaction and combination of many factors, highlighting: the attitude and emotion of the public, the influence of the people around them, the knowledge they have about the water system, the perceived risks, as well as the level of trust in the authorities that control, supervise or monitor the water, its specific use, the cost and the possible scenarios of scarcity of the water resource [14,15].

Paola, Mustafa and Giacomo, (2018) have pointed out that the investment, operation and maintenance costs of the processes at the end of the tube and the regulations that govern water quality; are the main limitations to complete treated wastewater reuse projects [16]. Saliba, Callieris, D'Agostino, Roma, Scardigno (2018) highlight that water quality is achieved through investments in infrastructure and changes in wastewater management, which is delayed due to lack of institutional awareness [14]. Psychometric studies indicate that intuition and negative emotions to reuse treated wastewater are generated in response to mistrust, fear and uncertainty that affect the perception of risk, a determining factor in public opposition and a dominant social factor, which affects the acceptance of water reuse [17].

Likewise, information and knowledge are directly related to the perception of risk, being the fear of the unknown what generates irrational emotions, which prevent or lead to the failure of investment projects; but when more information and knowledge are available, the advantages of reuse are better understood, this indicates that the greater the perception of benefit by future users, the greater the risk tolerance [17]. The comprehensive management approach is still difficult to achieve, contamination of water sources arises from illegal discharges; inefficient use of water, lack of integrated planning, and lack of evaluation of environmental and public health impacts exacerbate the problems [18].

The local or regional gaps include the lack of definition of roles at all decision levels and improving alliances, this is important to generate the trust of future users, in accordance with quality standards in integrated management [18].

III. Results And Discussion

Socioeconomic characteristics and problems of water supply for human activities in Kimbiri- Sampantuari

According to the INEI census (2017), the total population of Kimbiri amounts to 8,192 inhabitants, the urban area is made up of 1,564 men and 804 women between 18 and 65 years old; while the rural area is made up of 1,640 men and 1,524 women, for the same age range. In figures 3a and 3b, a similar population is also observed for those under 19 years of age [10]. Between 73 and 94% of the population know how to read and write because they have primary and secondary education.

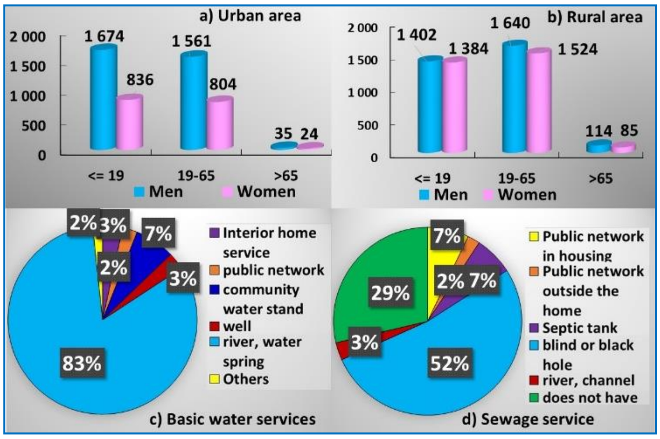

Fig. 3. Population statistics in Kimbiri Alto-Sampantuari: a) urban and b) rural, c) basic services and d) sewerage

However, 45-85% of the population does not work and is made up of mothers and students. The Sampantuari community, made up of the original Ashaninka people and settlers who make up part of Kimbiri Alto, is located 2 km downstream, near the projected site for the construction of the PTAR (local project)(See Figure 4).

The population is in full expansion, it currently has 109 homes while Kimbiri Alto has 1,250 homes. The growth rate of the general population is 2.4% and their homes are also made of wood, followed by those made of noble material. In Kimbiri Alto, urban expansion is appreciated, which does not have public drinking water and sanitation services and builds public intakes for its supply [19].

Fig. 4. Kimbiri Alto-Sampantuari: a) and b) Inhabitants, c) and d) Oxidation lagoons

In this area, a precarious agricultural productive activity of the VRAEM is developed despite having the available natural resources, it mainly develops agro-industrial crops: cocoa; coffee; corn; yucca; rice; highlighting the productive volume of coffee and cocoa with 38.67% and 36.01% respectively. Agricultural development is limited by the lack of water, irrigation is carried out by dry land; through obsolete processes and technical support. The area has

5,981.32 hectares of rainfed crops, depending exclusively on the rainy regime (November to March), sowing is done at the beginning of the rains to facilitate crop germination [19]. The quality of water from water sources causes diseases in the vulnerable population. Many times untreated water is consumed, mothers do not develop hygiene habits and children consume food without proper cleaning.

B. Perception on the reuse of treated wastewater

The results of the surveys are shown in Figure 5 for the dimensions studied. The general analysis of the farmers' perception of the risks of reusing treated wastewater yielded 72.6% negative responses, this perception was based on the criteria of health, water quality, trust and risk for its reuse in the crops. 100% of those surveyed believe that recycled water will not present healthy conditions, since in general they attribute the increase in diarrheal, skin and parasitic diseases to the poor state of the public network, drinking water supply and sanitation; even worse in areas that do not have both services. The Ministry of Health (MINSA) has reported between 2000 and 2021 a high number of cases of cumulative incidence (123.79) of these diseases in the district [20].

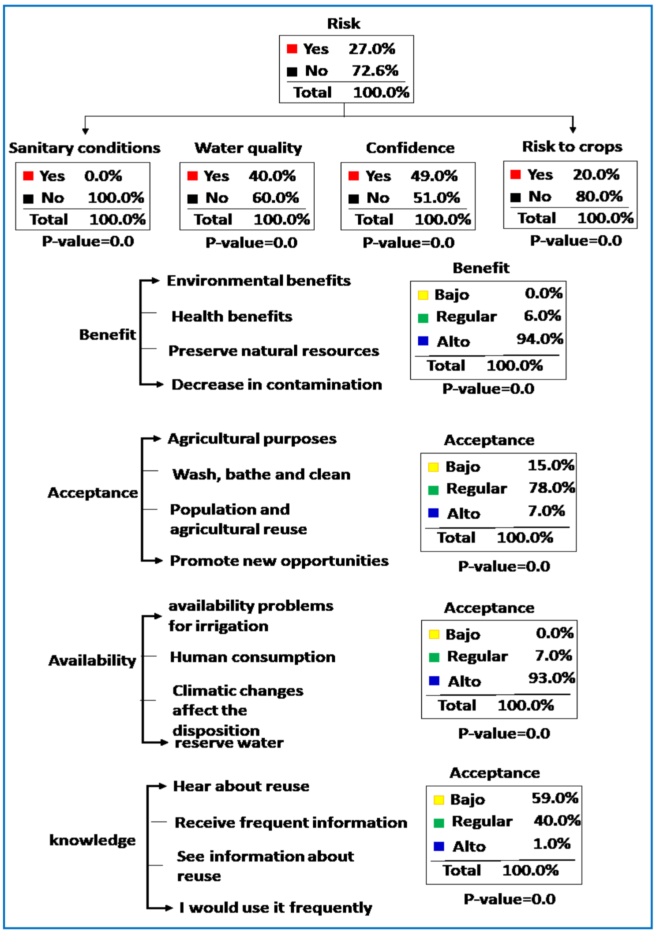

Fig. 5. Results of the survey on the perceptions of reuse of wastewater treated by the native and colonized community of Kimbiri-Sampantuari

Likewise, the respondents showed a divided perception about the quality of the wastewater treated for reuse, the vast majority (60%) think that there are risks, especially those who constitute part of the 84.25% of the inhabitants who use water from the river, ditch, spring or underground and of those who have a terrible supply-sewerage service [19], carry the stigma that the recovered water would be a health risk [21]. The results of the surveys are shown in Figure 5 for the dimensions studied.

On the other hand, 49% of the inhabitants showed greater confidence in reuse, under certain conditions that lead to a reduction in risk, as is the case in agriculture. In a similar study carried out in Lebanon, when asked about their willingness to reuse treated wastewater, about 50% of the interviewees answered affirmatively and the rest were not willing to reuse, the acceptance was related to the use for agriculture/landscaping/toilet flushing, etc. [7]. Likewise, only 80% of the farmers, residents and natives interviewed agreed to reuse water in their crops because they present less risk [19], the crops are long-stemmed and the fruit does not come into direct contact with the recycled water. According to Michetti (2019), farmers prefer to irrigate agricultural products that are not directly used by humans, such as alfalfa, since food safety is a concern for consumers [17]. Many enteric bacteria and viruses have been shown to be present at high levels in reclaimed wastewater [22].

Regarding the perception of the environmental benefit, preservation of natural resources, reduction of pollution and benefit to the health of the community by reusing recycled water, the response was positive (94%), and only 6% showed acceptance regular. According to Liu, He, Fu, Chen, Wang, Wang (2018), this perception is based on the awareness of the consequences of environmental pollution caused by human activities; which has a positive effect on people's moral standards, to protect the environment and accept the reuse of recycled water and, understandably, to protect the water resource [23].

The measure of acceptance of reuse for washing, bathing and cleaning was very low (15%), the level of human contact with the treated wastewater is crucial as it is believed to be disgusting once the water is contaminated with human waste [7]. However, the majority showed a fair level of acceptance (78%) for agricultural purposes, and only a high level of acceptance of 7%, promoted by new opportunities for the community. This perception is crucial considering that the supply of water decreases, especially during the dry season, then lasts for a long time when irrigation needs increase and the accelerated growth of population centers due to migration (settlers), exacerbating the water problem [24].

In addition, 93% of those surveyed showed a high availability to reserve treated wastewater for later reuse, and only 7% showed certain doubts, especially those that have drinking water networks; this network crosses cultivated areas that in certain occasions it is used for irrigation ignoring local regulations. Regarding the cognitive factors, the respondents know the problem of the scarcity of water resources, and its relationship with the scarcity of rains, which limits the accessibility to water.

The rivers have an irregular regime and are affected by the dry season, followed by rainfall variability, with recharge starting in November [19]. They also know that water pollution problems are increasing with the increase in urban settlements. However, there is a great lack of knowledge in the respondents (59%) due to the low level of information about the WWTP project and its benefits that they did not know how to answer; while 40% said they showed regular knowledge about the local project. This is consistent with other findings, which show that these events are related to the lack of information about WWTP projects [17].

C. Conceptual and regulatory model of the Water Cycle and the Integrated Management System in Kimbiri-Cusco (Perú)

Figure 6 shows the water cycle in the Kimbiri district, the drinking water supply system is not sufficient to cover the needs of the inhabitants of the area, on the one hand the Ashaninka natives and on the other the settlers who adapt to the way of life of the place with agricultural activities in conditions of poverty. The waters of the Kashiroveni River are captured for supply and join the San Luis River to form the Kimbiri River. The drinking water treatment and distribution lines do not fully supply a population that has been increasing in recent years, especially downriver in the entire area of Kimbiri Alto, where the population centers of Sampuantari are accentuated. Despite this, the water network crosses farms, where this resource is clandestinely used to irrigate crops, neglecting its savings, in dry seasons water is scarce and there are limitations in its supply.

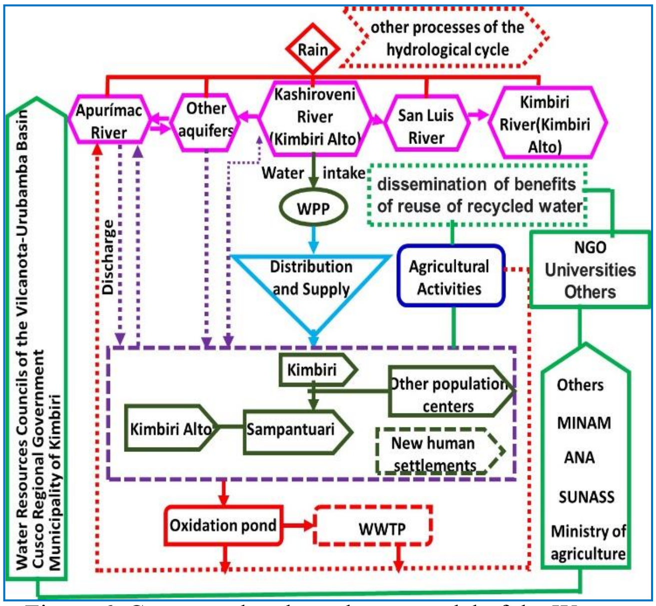

Figure 6. Conceptual and regulatory model of the Water Cycle and the Integrated Management System in Kimbiri-Cusco (Peru)

In the upper Kimbiri and in impoverished areas, the water extracted from different water sources contains pathogens, which cause enteric diseases in users, especially children and women who do not have a hygienic culture [24]. The residual waters are captured in the 4 oxidation lagoons of the district, to later be discharged into the Apurímac River, which also receives illegal discharges that end up polluting it.

The idea of establishing a wastewater treatment plant downstream, in the upper area of Kimbiri, turns out to be a viable alternative, to dispose of this resource in a stable manner, since it will not depend on the seasons of the year [18] and its reuse in the irrigation of agricultural land, would allow farmers new opportunities for their agricultural development in the context of a circular economy of water [25]. It is evident that the nature of the reuse is determined by the decision of the municipalities: the Regional Government of Cusco, which is in charge of the superior administration of the department of the same name, and by the Municipality of Kimbiri, directly responsible for the project, civil society in this case is the population involved, whose perception has a great weight in the acceptance or rejection of reuse [15].

Other relevant actors for the project are the authorities, such as the National Water Authority (ANA), the Ministry of the Environment (MINAM), the Ministry of Agrarian Development and Irrigation (MIDAGRI), the National Superintendence of Sanitary Services (Sunass), the Council for the Management of Water Resources and Hydrographic Basins of Vilcanota-Urubamba, which has been promoting in this decade the reuse of recycled water within the framework of the objectives of Sustainable Development, Law No. 29338 and the Law of Water Resources of Peru, although in a limited way, for example in Lima only 2% of treated domestic wastewater is reused for irrigation of parks and green areas in Metropolitan Lima [26]. In Perú, 7.8 m^3/s of the effluents produced in 145 WWTPs (43%) are used for agricultural irrigation and 4% generate 0.2 m^3/s for the irrigation of urban green areas, but each region has intrinsic characteristics that should be studied previously [27].

There is a regulation for the reuse of wastewater treated by a person other than the owner of the treatment system in order to protect and preserve the quality of natural water sources (Supreme Decree 005-201-AG)[28] and a guide for its implementation. Despite this, informality still persists in the face of spontaneous reuse, without control and surveillance mechanisms, and the regulatory and administrative difficulty for its formalization. The Municipality of Kimbiri must ensure a quality of recycled water suitable for agricultural reuse, currently not all WWTPs know the final quality of the effluents, nor the particular requirements of an agricultural area, such as nutrient content or the presence of enteric bacteria [27]. The sustainability of reuse is an important factor that compromises an environmental dimension, due to savings in water and energy consumption, to mitigate carbon emissions [17]; the economy is another relevant factor, which includes capital investment, payment from users to cover operation and maintenance, as well as certain subsidies to the indigenous people of the area; should be consistent with acceptability to the Kimbiri community and lower risk to human health [30]. The communication and awareness plan proposed by the municipality should be strengthened through strategic alliances with the universities, their volunteers and the area of university social responsibility; since it is an independent actor that enjoys the confidence of the population [17].

It is necessary to permanently consolidate the awareness, culture and value of water, knowledge of wastewater treatment technology and the benefits of its reuse, through reflection and analysis to generate acceptance; this will strengthen the goal of conserving water for domestic and non-domestic use [31]. This research has shown that the farmer with more education has an inverse relationship with the perception of risk [31], and despite his distrust in the quality of recycled water. It also considers that Reuse is beneficial for crops, thus showing a perception of less risk. Furthermore, Micheletti et al. (2019) [31] points out that knowledge is not a determining factor, as long as there is a diffusion mechanism that directly influences the personal decision, since the availability of information improves the generation of trust; especially under the criterion that if others do it, it must be for something very good.

It is important to mention that this research has been limited to collecting initial information on the perception of the inhabitants and users and it has not delved into quantifying the final results of the application of strategies aimed at the acceptance of the project. In this context, the participation of the academy is crucial because it strengthens the knowledge and acceptance of those involved in these water recycling projects. In addition, based on this experience, valuable recommendations have emerged to develop studies and interventions in areas where there is a lack of water or limitations to its use, especially in the coastal area of the country.

IV. Conclusion

The perception about the reuse of recycled water in agriculture in a vulnerable population of the Sampantuari district of the Kimbiri district (Cusco) has been investigated. Respondents perceive a high level of risk in reuse, based on their distrust in the quality of the final effluent; influenced by the constant enteric diseases they suffer, by the use of different sources of untreated water and the lack of knowledge of the project. The environmental awareness of the respondent improved their perception to accept its reuse in agriculture. It was also observed that a higher level of knowledge about the project and education decreases the perception of risk; however, alliances must be strengthened with universities and authorities to raise awareness, train and improve acceptance of the reuse of recycled water, in the context of sustainable development and a circular economy of water for the benefit of the Sampuantuari-Kimbiri community.

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