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Problems and possible solutions to environmental impacts of small hydropower plants in Turkey

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ABSTRACT Energy is a significant matter in the generation of wealth and plays an important role in economic development which makes energy resources extremely important in the world. Nevertheless, energy generation has caused various kinds of problems. This study, therefore, intended to deal with the solution proposals to the environmental impacts of Small Hydropower Plants (SHPs) in Turkey. To this goal, Turkey's energy sources and demand, and the potential of SHP to meet this demand are briefly reviewed. The main reasons for environmental problems related to the application of SHP projects in Turkey are discussed with some case studies. Most of them are obtained from field reconnaissance studies during administrative law views in Turkey. In this context, the main environmental problems, including environmental flow, cumulative effects of various SHPs in a basin, environmental destruction, etc., are studied. The causes of public backlash to SHPs are especially focused. The main reasons for the public backlash are classified into three categories; related to construction and operation of the plants and cumulative impacts of various SHPs. Depending on the results of various case studies, some possible solutions, to solve the environmental problems and to mitigate the public backlash, are presented at the end of the paper. The main outcome of this study is to provide some solutions to the environmental impacts of SHPs.

Keywords: Small hydropower plants, Energy generation, Environmental impacts of SHPs, Operational problems in Turkey.

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1. INTRODUCTION

Energy is considered as a significant matter in the generation of wealth and plays an important role in economic development. This makes energy resources extremely important in the world, and thus, countries have focused on the energy sector intentionally [1, 2]. The rapid increase in population and industrialization in the 20th century has created a high energy demand [3]. Conventional fossil fuels are the main sources that provides the economic progress. While the benefits of these sources are broadly known, those have many environmental impacts also. Pollution in the form of increased carbon emissions, acidification of meteoric water, and destruction of natural landforms in the pursuit of natural resources are just a few of the known negative impacts of conventional energy sources. As for Europe, the issue of greenhouse gas emissions is becoming increasingly important. European Union countries are continuously working to reduce these emissions by using new technologies for renewable energy sources, including geothermal, solar, wind, or hydropower energy [4].

The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution, and consumption. Fossil fuel-oriented energy sector has been accused of being the main source of global warming. Increased awareness of climate change and international agreements such as the Kyoto Protocol have forced the governments to search for alternative energy sources, and increased oil prices have also accelerated this process. Within this conjuncture, governments are forced to pay more attention to renewable energy technologies, and investors are motivated to establish renewable energy technology based business. Among these technologies, hydropower, a renewable energy source based on the natural water cycle, has been considered to be the cheapest and the most widely used technology that is available. Hydropower has been used for more than a century, and it is the first source of electricity for 55 countries [5]. Hydropower has very few greenhouse gas emissions compared with other large-scale energy options. On the other hand, hydropower projects do not export impacts such as acid rain or atmospheric pollution [3].

Although hydropower appears to be the cleanest and most versatile of renewable energy sources, experiences show that optimism about its potential can be misplaced, and small hydropower plants (SHPs) have also some malign impacts. Small-scale hydropower schemes (SHS) tend to have a relatively modest and localized impact on the environment. These arise mainly from construction activities and changes in water quality and flow on ecosystems and water use. The impacts of small-scale hydropower schemes are likely to be small and localized, providing best practice and effective site planning are used. But the fact is, it gives no evidence whatsoever to support the conclusion that the impacts will be "small and localized". Likewise, methane generation occurs largely where water and sediment meet, and this means that a shallower water body is likely to release more methane per unit area than a deeper water body [6].

Large-scale hydropower plants also involve a complex relationship with environmental integrity. Like many other developmental activities, it has also adverse impacts such as disruption of sediment transportation, fish migration, downstream flows, and estuaries [7]. Public opinion about energy sources is a critical factor in the successful development and management of new energy technologies. Understanding public attitudes and the issues that may affect support for or opposition to hydropower projects is key to facilitating the development and deployment of this technology [8].

Because Hydroelectric Power Plants (HEPPs) are an important renewable energy resource and provide efficient, reliable, and relatively low cost of electricity production, they are considered an important electricity production option. However, the rapid development of large hydropower plants in recent years, especially in developing countries, has led to debates on economic, social, and environmental issues. In Turkey, as it is in the world, there is an increasing trend towards renewable energy sources. The increases in oil and natural gas prices cause the electrical energy obtained from fossil fuels to become quite costly for Turkey. In Turkey, of the total electricity generation in 2018, 31.0% was obtained from natural gas, 38.0% coal, 21.0% HEPP, 7.0% wind, 2.0% geothermal and 2.0% other sources [9]. In line with its local and national energy strategy, Turkey is taking the necessary steps to reduce this dependency.

In Turkey, various power plants that are in the project, establishment, or operation phase are always on agenda due to concern on possible potential impacts on the natural and social environment as well as about the possible negative impacts that can arise in the future. There are specific arguments and even confrontations that take place between the company, which is constructing the electrical energy plant, and the local public living near the construction. Sometimes the security forces are forced to intervene. The matter goes to the courts, and the investment stops during the legal litigation [10].

In this study, important environmental impacts of SHPs in Turkey are studied by using data of some case studies, most of them are obtained from field reconnaissance studies during administrative law views. In the context of environmental impacts, the causes of public backlashes to SHPs are especially emphasized. The main environmental impacts of SHPs are classified into three groups. The first group problems include construction problems, which arise during the construction of SHPs. These involve erosion and landslides, vibration and noise, deposition of excavated material, dust emission, and harms to flora and fauna problems. The second category, operational problems, have longer-term impacts than the construction problems. The most important is related to environmental flow, during both calculation and control stages. The other important operational issues are found to be related to fish and wildlife passages, destruction of sediment regime power lines. Last but not least matter is about the cumulative impacts of various plants within or near to basins and bearing capacities of watersheds.

Some possible solutions to minimize the negative environmental impacts and therefore to mitigate the public objections are presented at the end of the paper. These solutions are divided into six categories. The first two categories are relevant to construction and operational impacts, solutions to construction and operation problems. Problems related to Environmental Impact Assessment Reports (EIARs) are especially emphasized because a lot of public backlashes are found to be on EIARs, which are categorized as requisite, and contents and qualification of EIARs. In the context of possible solutions, a special weight has been given to Cumulative Environmental Impact Assessment Reports (CEIARs), an important issue, which is generally slighted and omitted in Turkey. As an integrated approach to the environmental problems, the Integrated River Basin Management (IRBM) approach is also introduced. At the end of the paper, some key criteria and a checklist on the eligibility criteria for SHPs are also presented.

There are several studies on the environmental impacts of SHPs both in Turkey and worldwide. This paper aims to contribute to attempts to solve the negative environmental impacts and problems regarding with the public backlash to SHPs. In this context, the main environmental problems, including environmental flow (low flow), cumulative effects of various SHPs in a basin, environmental destruction, etc., are discussed.

2. TURKEY’S ENERGY SITUATION

2.1. General

Turkey is situated at the meeting point of three continents (Asia, Europe, and Africa) and stands as a bridge between Asia and Europe. Because of its geopolitical position, Turkey can be considered as a bridge for energy to connect Europe to Asia and the Middle East. Turkey has improved its economic situation in recent years, and this has caused more energy needs, which means more consumption and more imports [1]. Turkey’s natural energy resources are quite miscellaneous, for example, hard coal, lignite, asphalt, oil, natural gas, hydropower, geothermal, wood, animal and plant wastes, solar and secondary energy resources, coke, and briquettes. These resources are produced and consumed in the country. Turkey does not own large fossil-fuel reserves. In the future, it seems that it will be very difficult to meet the anticipated demand for oil, natural gas, and even coal. On the other hand, Turkey has big reserves of renewable energy sources [11]. In Turkey, where there is no nuclear power, electricity is produced by thermal power plants, consuming coal, lignite, natural gas, fuel oil, and geothermal energy; and by HEPPs [12].

Turkey's demand for energy and natural resources has been increasing due to economic and population growth. In recent years, Turkey has recorded the fastest growth in electricity demand among OECD members, with an annual growth rate of 5.5% since 2002. Turkey's energy use is expected to increase by 50% over the next decade [13].

Turkey, with a population of 82 million, is an energy importing country and dependent on the imported energy sources. Energy demand and dependency on imports in the Turkish energy market is growing. Turkey's increasing energy demand is mostly met by fossil fuels, of which a large portion is imported [14]. In line with its local and national energy strategy, Turkey is taking the necessary steps to reduce this dependency. The main elements for Turkey's energy strategy are prioritization among energy supply security-related activities consideration of environmental concerns all along the energy chain; increasing efficiency productivity and efficiency; and increasing research on energy technologies.

2.2. Renewable Sources

Indigenous production by using national resources is important in reaching energy without being dependent on external energy resources. Therefore, indigenization is very important for Turkey to add a new dimension to its policies and strategies for the reduction of the country's years-long import dependency. Many public and private sector institutions and organizations have spent tremendous efforts to increase the use of national energy resources. Increasing production from indigenous energy resources is critical in terms of ensuring the security of supply for Turkey. In this regard, significant efforts have been made to meet energy demand by using indigenous resources. Accordingly, renewable energy investments that aim to bring natural resources into the economy are extremely critical for diversifying energy resources [15].

To analyze Turkey's plans for increasing its renewable energy sources, understanding its motives in the context of the larger energy strategy is a key issue. Turkey aims to achieve greater energy independence and trying to decrease the economic burden of energy imports. Turkey has embarked on a strategy of aggressively developing its domestic resources [16]. The renewable energy sources that the Ministry of Energy and Natural Resources has launched to reduce the dependence on foreign energy, constitute one of the important steps in the National Energy and Mine Policy. According to the Turkey Investment Support and Promotion Agency, the most important Turkish government's targets in the energy sector by 2023 are: Raising the total installed power capacity to 120 GW, increasing the share of renewables to 30%, extending the use of smart grids and commissioning nuclear power plants [17].

2.3. Small Hydropower Plants

SHPs are hydroelectric systems that harvest the energy from flowing water to generate electricity in the absence of a large dam and reservoir, which is how they differ from conventional impoundment hydroelectric facilities. A small dam lake, called a regulator or weir, is generally used to ensure enough water goes in the penstock, and possibly some storage may be available. SHPs have wide usage in Turkey, especially after 2003, when the production of hydroelectric energy was legally allowed by the private sector. After then, hundreds of Run of the River (ROR) HEPPs have been designed and constructed, which has resulted in various kinds of environmental impacts. These impacts are generally related to the construction and operation stages of these structures. There are many studies that deal with these impacts [18-20].

SHPs are electrical power plants that use the flow within a river channel to generate electricity, without the need for water storage as shown in Figure 1. Most of the SHPs are have been made of as ROR HEPPs. A proportion of river flow is taken from the river (usually on a weir or a side-channel), diverted down a secondary channel towards a HEPP turbine, before being returned to the main channel further downstream. Channel obstructions (typically weirs) regulate water levels, allowing a proportion of flow to be diverted down a secondary water channel to a turbine before it is returned to the main channel further downstream. SHPs use the kinetic energy of a river to drive a turbine or propeller in the water channel, without barriers or flow diversions. The primary difference between this type of hydroelectric generation compared to others is that ROR primarily uses the natural flow of water to generate power instead of the power of the water falling a long distance. Another main difference between traditional hydropower plants is that ROR HEPP is used in areas where there is little no water storage, such as in a river. The main advantages of ROR HEPPs are: they provide cleaner power with fewer greenhouse gases since they store less or no water, some problems of storage water, such as flooding and degradation of water, do not occur. The main disadvantages are: their energy production depends on the discharge of the stream, therefore they produce unstable and unreliable energy; if the stream dry, no energy will be produced. Another important concern is related to environmental flow, which will be discussed in detail in the paper.

The first installed power of the HEPP, which was established in Tarsus in 1902, was 2 kWh, and then it was increased to 60 kWh until 1915. After the State Hydraulic Works (DSI) was established in 1954, projects were better funded, and the power produced per year was greatly increased. Turkey is situated in a semi-arid region and has a significant hydropower capacity, estimated at some 433 GWh per year in total, of which some 125 GWh per year is thought economically viable [14].

The theoretical potential is 433 billion kWh and is one of the most significant possible sources for the country. The technically feasible potential is 216 billion kWh, and the economic hydroelectric potential is 140 billion kWh/year. In 2017, hydroelectric power generated 58.2 billion kWh of electricity. As of the end of June 2018, 636 HEPPs, which have 27.912 MW of installed capacity, corresponded to 32% of the total installed power in Turkey [17]. Due to the increasing dependence on foreign sources of electricity generation, Turkey has revealed the necessity of the full assessment of hydropower capacity. One of the referenced solutions to close this energy necessity is the construction of ROR HEPPs which are established in streams.

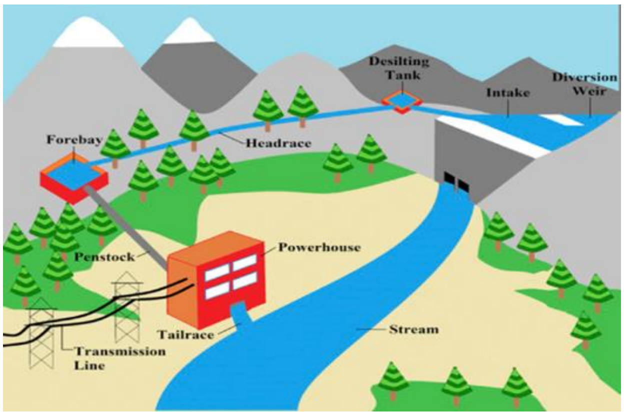

Fig. 1. Schematic diagram of run off the river hydroelectric power plant

Although the theoretical potential of HEPP is 433 billion kWh, there is some discussion in calculating the economic potential of Turkey depends on the criteria, which has been considered in calculation what is the feasibility of HEPPs. A discussion on this subject can be found in Yüksek, 2008, [1] where the HEPP potential was estimated as 188 billion kWh.

3. ENVIRONMENTAL IMPACTS OF SMALL HYDROPOWER PLANTS IN TURKEY

Hydropower is a key-source for renewable electricity generation and has an important potential to be marketed as green power. While offering ecological advantages from a global perspective, such as climate change mitigation, emergency management, and reduction of flooding risk, the construction and operation of HEPPs may cause some detrimental environmental impacts on the local and regional level. The terms “impact” and “effect” are often used interchangeably; both terms aim to describe any change that the project may cause in the environment. These include harm to fish populations, a loss of aquatic habitat, a significant variation in natural flow regimes, and deterioration of the landscape. As a result, a contrast between two different but well-grounded environmental goals seem insoluble: Green-house effect reduction, on the one hand, and water habitat protection, on the other hand [21].

In the recent past, there have been protests by various environmental groups and the residents of the locality of proposed hydropower projects, against these projects. This aroused awareness in the public, of the question, is hydropower generation as environmentally friendly as it had been commented [22]. Even though renewable energy projects are regarded as “*green energy*”, there are some negative effects of those on the environment. Table 1 lists the main positive and negative environmental impacts of hydropower systems.

Table 1. Main environmental impacts of hydropower systems

Positive Impacts	*Negative Impacts*	
-	*Type of Impact*	*Damage*
Produces no pollutants, no waste Enhances air quality Avoids depleting non-renewable fuel resources	Water Diversion	Inundation of terrestrial habitat, Modification of hydrological regimes Downstream flow reduction Modification of aquatic habitats
Enhances knowledge and improves the management of valued species	Anthropogenic Structures	Visual intrusion Movement barriers for fish and animals
Neither consumes nor pollutes water for electricity generation	Operation of Plants	Noise and electronic emissions

Various power plants that are in the project development, establishment, or operation phase in Turkey are always on agenda due to concern on possible potential damages to the natural and social environment as well as about the possible damage that can arise in the future. There are certain arguments and even confrontations that take place between the company which is constructing the power plant and the local public living near the construction. These confrontations take place, and sometimes even the security forces are forced to intervene. The matter goes to the courts, and the investment stops during the legal litigation. The main issue of the expertise is related to Environmental Impact Assessment (EIA) reports, either to "document of EIA is not necessary" or to "acceptance certificate of EIA". The main data for this paper are obtained during these viewing studies, both in the field listening and noting annotations of all of the juridical sides and the people, and in-office scrutinizing the field observations and case documents. Additional data have been attained by evaluating some media news, related to the subject.

The observations and data have been evaluated in the context of the subject. During this process, the main environmental impacts, and reasons for the public backlash to SHPs are especially focused. Within this context, a total of 29 expert reports are evaluated. These reports are related to various kinds of environmental effects of SHPs, during both construction and operation of these plants. The evaluated projects are located in six Provinces, two of them (Trabzon and Rize) are located in the Eastern Black Sea Region, two (Ordu and Tokat) in the Central Black Sea Region, one (Erzurum) in the Eastern Anatolia Region, and one (Sivas) in the Central Anatolia Region. In other words, the spatial distribution of the data is good, and the data can represent Turkey. The number of data (29) is also high to make general decisions. During legal viewing, various kinds of questions have been asked by Judge to Experts, most of which are related to probable environmental effects of SHPs and about requisite of EIA, and if an EIA had been prepared, its suitability and acceptability. A summary of the conclusions of the reports is presented in Table 2. As it can be seen, almost all cases (95%) have concluded that EIA is necessary. 6 cases, out of 10 (60%), related to acceptance of EIA have resulted in acceptance and 4 (40%) have concluded their rejection.

Table 2. Summary of the conclusions of IEA reports

Question	*Yes*	*No*
Is it necessary?	18	1
Is it accepted?	6	4

At the end of the evaluation processes of both field and office studies, the problems about the environmental impacts of SHPs are classified as problems related to construction and operation processes and about the cumulative impacts of various projects.

3.1. Construction problems

These problems are related to environmental impacts that arise during the construction of SHPs and on the areas within or in the vicinity of the project application. Although a great number of problems are encountered during the construction processes, these problems can be classified as follows:

a) Erosion and landslide: SHPs are generally made as to the run of river type, without any important water storage, and their power are related both to discharge and head (elevation difference); therefore, to gain head, they must be constructed in steeply sloped lands, which have great potential and risk of erosion and landslide. The construction of SHP facilities, such as weirs, intakes, settling basins, transmission plants, penstocks; causes to the destruction of equilibrium slope and increases the risk of erosion and landslide (Figure 1). A great amount of lumbering has been made during the construction process and this also aggravates the equilibrium state, which also increases the associated risks. Road construction is another great threat to aggravate erosion and landslide.

Fig. 2. Landslide in Büyükdere HEPP, Keşap, Giresun

b) Vibration and noise: During construction, various kinds of vibration take places, and these vibrations generate high noises, they discomfort the people in the vicinity of the facilities, and sometimes causes diseases. The main sources of vibration and noise are vibratory compaction machines, track type, and wheel loaders and bulldozers, various kinds of trucks, lifts, excavators, cranes, etc. Vibration and noise also disturb, both wild animals located in forestry areas and migrating birds.

c) Deposition of excavated material: Although the excavated materials, which emerged during the various constructions, must be stored in the temporary storage areas, they are often poured on the stream beds. These causes filling up the stream beds and degradation of water quality, which have resulted in various kinds of aquatic environmental problems and sometimes in fish deaths. This stored material also leads to deterioration and sometimes disappear from local flora and fauna.

d) Dust emission: In due course of the excavation process of various parts of SHPs (weirs, transmission channels, etc.), dust emission is generated during grubbing up, loading, carrying, and unloading of soil material. These emissions are detrimental to people's health, especially for the growth of vegetation and trees, therefore for honey production.

e) Harms to flora and fauna: Construction of weirs causes the riverine habitat to turn from a lotic ecosystem to a lentic one, which in turn leads to a decrease in algae habitats and benthic algae. Various kinds of construction activities bring about destruction in the local vegetation, also disturb fishes and other aquatic species.

Out of these impacts, three effects "erosion and landslide", "deposition of excavated material" and "harms to flora and fauna" have long-term effects and can be assumed as "permanent impacts". However, the duration of the other two impacts ("vibration and noise" and "dust emission") is short, and they are classified as "temporary impacts".

3.2. Operational problems

These problems are related to environmental effects encountered during the operation processes of SHPs. In contrast with construction problems, they are not restricted to the areas in the vicinity of the project application; their influence areas are wider. Moreover, despite construction problems are limited with construction duration (1 to 3 years), operation problems are persistent through the operation (40 to 50 years). Several problems are encountered during the operation process; a summary of them are as follows:

a) Environmental flow: Environmental flow (low flow or minimum flow) is defined as the flow (discharge) that is necessary to ensure the existence of habitats in a river. It is highly probable that environmental flow is the most important and most hotly debated issue related to SHPs. Water infrastructures in riverbed cause some impact on water quantity, water quality, and the water ecosystem. So, the determination of necessary low flow becomes an important problem to protect the downstream water ecosystem. Low-flow calculations are made for the determination of water amount, which is released from HEPP to downstream, domestic use, irrigation, water pollution studies, and determination of the required amount of water for the sustainability of aquatic life. Water at the weir is carried to a certain level, and then energy is produced by dropping that water to HEPP using penstock. In that case, the environmental flow amount, which is essential for the sustainability of aquatic life in the dry section of the river becomes important. Since this amount of water cannot be used in energy production, this water decreases the project rantability. Therefore, on the one hand, enterprises tend to keep this value as low as possible; on the other hand, it must be as high as possible for environmental considerations. There are a lot of methods to calculate the environmental flow that requires water habitats. Each method takes different properties of water habitat into account. The calculation methods are mainly classified into four groups: hydrological, hydraulic rating, habitat simulation, and holistic methods. There are

several subgroups of these groups, such as Tennant, 7Q, Flow Duration methods. In Turkey, 10 percent of the last 10-yearly daily discharges are generally chosen as environmental flow. However, this ratio (0.1) should not be a constant value and must be calculated depending on local conditions, such as flora and fauna, stream characteristics, etc. In addition to determination, another very important problem is control of the environmental flow. In application, active control on whether the environmental flow has been allowed to the streams is a big problem. Consequently, as a result of failures both in the determination and control of environmental flow, various kinds of environmental problems have arisen. Both office and field studies have revealed that the calculation, and more importantly the control, of environmental flow, is the most important public objection and backlash. Most of the people worry about that, in case of construction of SHPs they will be devoid of even drinking water; other concerns related to water decrease because of SHPs are focused on irrigation, on the sustainability of aquatic flora and fauna, and watermills.
b*) Fish passages:* Since the weirs are barriers to fish migration, fish passages (fishways). Although fish passages are being built, its mandatory is delayed, and the system is mostly not operated, and active control is imperative. Although in EIARs it is written that "fish passages will be established", in application it has not been made real, which has seriously endangered fish life.

c*) Wildlife passages:* Construction of several parts of SHPs necessarily prevents animals from walking about places, where they are used to walk. To avoid this important drawback, appropriate wildlife passages must be made. The reports prepared upon the request of firms and presented to the Ministry of Forestry and Water Affairs emphasize that the construction of passages for large mammals and small terrestrial mammals are required and wildlife passages without banisters should be constructed at certain distances to ease the animal passages along the way based on high priority species and ecosystem features [23]. Despite this legal obligation, in practice, it has been frequently observed that almost no measure has been taken for maintaining the wildlife passages. This situation is a very important threat to wildlife in the vicinity of the SHPs and is observed to be one of the most serious public concerns.

d) Destruction of sediment regime: Since the natural flow conditions are destroyed, the sediment transport regime in the streams has also become unbalanced, and a generally significant amount of sediment is accumulated on the upstream of weirs, riverbeds, and banks. As a result of the violation of natural sediment balance, local sediment erosion problems have arisen in streams, besides, since the transported sediment by streams to coasts reduces, coastal erosion occurs. Although this coastal erosion problem is more serious on the downstream of rivers, on which dams are constructed (for example, nearly 900 m coastal recession is measured in Bafra Coast, on the downstream of Kızılırmak River), similar and less severe problems are determined for SHPs [1].

Fig. 3. Destruction of vegetation due to power lines

3.3. Cumulative impacts of various SHPs
a) Summary of cumulative impacts: The impact of human activity or a project on an environmental resource or ecosystem may be considered insignificant when assessed in isolation, but it becomes significant when evaluated in the context of the combined effects of all the past, present, and reasonably foreseeable future activities that may have or have had an impact on the resources in question. Cumulative effects occur as interactions between actions, between actions and the environment, and between components of the environment. These "pathways" between a cause (or source) and an effect are often the focus of an assessment of cumulative effects. The magnitude of the combined effects along a pathway can be equal to the sum of the individual effects (additive effect) or can be an increased effect (synergistic effect) [24]. A conventional project and site-specific approach to environmental assessment have its limitations when it comes to assessing potential cumulative effects on environmental resources. Cumulative impacts are changes to the environment caused by an action (project or project activity) in combination with other past, present, and future human actions. As was stated by Pang et al. [7] “in the real operation of SHP plants, many river ecosystems are seriously degraded because of the over-development of water resources currently". A Cumulative Environmental Impact Assessment (CEIA) is an assessment of these impacts. In practice, assessment of cumulative impacts requires consideration of other assessment concepts, which are different from the conventional approaches used in EIA. Some of these concepts are the following:
-Assessment of impacts during a long period into the past and future.
-Consideration of impacts on Valued Ecosystem Components (VECs) due to both the project of concern and interactions with other past, existing and reasonably foreseeable future actions.
-Evaluation of significance in the consideration of other than just local and direct effects (such as indirect impacts, cumulative impacts, and impact interactions); and
-Assessment of impacts over a larger (i.e., “regional”) area.

b) CEIA and EIA: Cumulative impacts are not necessarily very much different from impacts examined in an EIA; in fact, they are generally similar. Much EIAs focus on a local scale in which only the footprint or area covered by each project component is considered. A CEIA further enlarges the scale of the assessment to an almost regional level. For the practitioner, the challenge is to determine how large an area around the action should be assessed, for how long, and how to practically assess the often-complex interactions among the actions. In all other ways, CEIA is fundamentally the same as EIA and often relies on established EIA practice [24]. The assessment of cumulative impacts should not be thought of as separate from the EIA process. Indeed, the assessment of such impacts should be an integral part of all stages of the process. The potential for these impacts to occur should be considered during the following stages: Scoping, collection of baseline data, assessment of impacts, development of mitigation measures, analysis of alternatives, and development of management and monitoring plans. The following requirements for considering the cumulative impacts of projects might be incorporated into the EIA terms of reference for carrying out EIA studies [25]:

-Define project activities along with other existing, in progress or planned projects (for the reasonably foreseeable future) in the region that could contribute to cumulative effects on Valued Ecosystem Components (V ECs).

- Identify the area of influence for the project (which may vary for different types of potential impacts).

- Identify the time boundary for the study, especially regarding considering actions in the reasonably foreseeable future (e.g., a concomitant construction period or operation). Scenarios can be developed to identify temporal boundaries as well, particularly when there is uncertainty.

- Identify possible VECs in the region in or close to the project's area of influence.

-Identify the VECs in the area of influence that should be considered in the study based on information related to current or anticipated future conditions, the existence of protected species or habitats, and the presence or anticipated presence of other human activities that would (adversely) affect the VECs; and

-Identify Project-Specific Standards (PSS), including relevant regulatory and/or international thresholds and standards (providing information on the carrying capacity.

Once requirements related to the assessment of cumulative impacts are incorporated into the project-specific EIA format, the adequacy of the assessment of the cumulative impacts in the EIA report should be checked during the review phase. This phase must ensure that cumulative impacts are addressed in the project EIA.

c) Case of CEIA in Turkey: Turkish Government promoted investments in HEPP projects as a policy priority in response to concerns about the environmental and climate change impact of other power generation technologies, as well as with an eye to compliance with EU regulations and targets. The rapid growth in investments raises concerns about the associated impacts (such as minimum environmental flow, temporary/permanent roads opened for the investment, etc.) and the significance of the cumulative impact of multiple HEPP projects on the river basins. Despite its importance, in applications, CEIA has not been considered important, as it deserves. Nearly all the SHPs are separately designed and the impact of a project on others or the related environment, also cumulative impacts of several projects have not been taken into consideration. Within the context of "cumulative impacts" of SHPs, another important concept has emerged, "the bearing capacity of an area (region, basin, catchment, etc.)", which is the maximum capacity for an area can bear without ruining the basic environmental characteristics of the area. This concept is mostly related to the number and/or physical characteristics (power, discharge, impact area, etc.) of SHPs. For example, suppose that, in a basin, if the number of SHPs is less than N or total capacity is less than B (MW), no significant degradation will occur. (Of course, the figures of N and/or B must be determined by detailed hydrological and environmental studies within the area in question). If the number and/or capacity of SHPs exceeds the related critical values (N and/or B), then significant problems are expected in the area. In Turkey, however, no appreciable and significant study has been carried out for the bearing capacities of the areas. As a result of this callousness, in most of the hydrological basins, an uncontrolled and unlimited number of SHPs are constructed, being constructed, or planned.

4. SOLUTION PROPOSALS TO SHP PROBLEMS

Possible solutions to the problems can be obtained comprehensively and in detail examining the reasons for the problems; the solutions are closely related to the causes of the problems; construction and operation problems. In addition to these problems, in Turkey, problems related to environmental impacts (EIA) and cumulative environmental impacts (CEIA) are also must be addressed. As an integrated approach to these problems, the Integrated River Basin Management approach is also introduced. At the end of the chapter, a checklist on the eligibility criteria for SHPs is presented to help checking the achievement and suitability of the remedies.

4.1. Solutions to construction problems

First, during the site selection stage for the SHP projects, the designers must scrutinize the possible sites, where the construction of SHP would be less harmful to the environment. The other significant point is to construct the related structures as less detrimentally as possible. This includes several components; preparing the construction areas for construction to transport the material and from employing well-trained staff to use suitable machinery, etc. Erosion and landslide are among the most construction problems and can be mitigated by various kinds of technical (structural) measures. These include land treatment and gully and stream course improvement measures. The main purpose of land treatment measures is to regain a ruined natural balance; these include melioration trenches, grading ditches and basins, knitting fences; forest development methods, afforesting with terracing, etc. Gully and stream course improvement measures include vegetative (fast-growing local trees and brushes) and structural measures (ground sills, levees, etc.). All noise-generating equipment must be inspected and maintained, suppressors and mufflers should be used and noise levels at the site and the closest area must be measured regularly. If extensive wood chopping operations are necessary, the usage of both suitable staff and machinery will considerably lessen the emission and noise and will diminish harms to flora and fauna. Most of the excavated material can be used in backfilling, in crushing-screening plants, road improvement studies and the problems related to its deposition may diminish. Harms to flora and fauna may be decreased by proper environmental measures. For mitigation of dust emission all heavy equipment should be inspected and maintained, unpaved roads should be daily watered and air quality should be monitored regularly.

4.2. Solutions to operation problems

The most important operational problem is related to environmental flow, both in determining and controlling stages. Detailed hydrological and environmental research must be carried out to determine the amount (discharge) of minimum discharge. Moreover, not only the discharge but also some important hydraulic parameters of streamflow must also be included. For example, water depth is a crucial parameter for surviving the aquatic animals; similarly, water velocity is often considered to be a very important parameter for aquatic species. A greater problem is about controlling of environmental discharge. Strictly control can only be made by more qualified DSİ personnel, equipment, and gauging network. Fish and wildlife passages must be certainly constructed. The problem of the destruction of the sediment regime can be diminished by proper design and structural measures. In general, the problems related to High Voltage Power Lines (HVPL) should not include EIA reports; additional detailed reports must be prepared about problems and solutions of HVPLs.

4.3. Environmental impact assessment reports

a. Requisite of EIA reports: Probably the most important challenge on SHPs has been related to EIARs. According to Turkish Environmental Law (Article 2, "Definitions"), Environmental Impact Assessment (in Turkish known as "ÇED") is defined as "studies to be pursued in the determination of positive and negative environmental aspects of the planned projects and determination of possible measures to prevent or to decrease the negative effects". The decision of "EIA is required" states that the environmental impacts of the projects subject to selection and elimination criteria should be examined in more detail. "EIA is not required" the decision states that the projects do not have important environmental effects. According to EIA Regulation, "EIA is required only for hydropower plants with at least 10 MW", thus for SHPs with less than 10 MW, only a "Project Information File (PIF, in Turkish PTD) is necessary, and "EIA is not required" document has been given to this kind of projects. However, this file gives only general and undetailed information about the project. Main headings in PIF are properties of the project, location of the project, and alternatives to the project and the location.

As it can be noticed, in PIF, no significant analysis is made about environmental impacts and possible solutions to the proposed project. Despite this fact, for SHP projects, of which their power is less than 10 MW, a significant percentage of all the SHPs, it has been concluded by Government that, only "PIF is sufficient" and "EIA report is not necessary". First, in deciding the decision of whether EIA is necessary, if and only if "power of the plant" is chosen a criterion. This is a significant shortcoming and mistake for assessing the environmental impacts of a plant. In addition to power, several additional parameters, related to hydrological and environmental properties of the related stream and project area, must be taken into consideration. As a result of this inadequacy, for most of the projects, with EIA is not necessary, people or local organizations resort to judgment, and as can be seen in Table 2, most of the judgments have concluded that "PIF is not sufficient and EIA report is necessary". This mistake in EIA Regulation must be urgently amended as "regardless of their powers, for all of the hydropower plants EIA is necessary".

b. Contents and qualification of EIARs: As was explained, the main purpose of EIA reports is to provide information on the potential negative and positive environmental and social impacts of the project. They also aim at making recommendations for the mitigation of the potential negative impacts and enhancing the positive ones. During the preparation stage of EIARs, a field survey of the related project site is conducted, and potential environmental impacts of project activities are identified, assessed, and documented and the EIA Team carry out consultations with various stakeholders, particularly lead agencies, local authorities, and the affected people. The main headings of the EIA Report are:

• Project description: location, aim, necessity and importance, related structures and facilities, construction activities, etc.

• Environmental baseline data: Physical environment (geology, climatology, air quality, flora, and fauna, etc.), biological environment (wetlands, vegetation, wildlife, etc.), social environment (land use demography, etc.),

• Potential environmental impacts and mitigation measures: Construction phase (physical and chemical, biological, socio-economic, etc.), operation phase (physical and chemical, biological, socio-economic, etc.),

• Analysis of alternatives

• Public participation: participation of people likely to be affected by the project and reflecting the public opinions in the EIA.

EIARs have generally been prepared by hydrology, geology, biology, forestry, environmental, etc. experts. However, it has been observed during this study that most of the EIARs are not satisfactory for various reasons. The main reasons are 1). They are not basin-based studies; 2). They do not consider the cumulative impacts of various projects; and iii. There have been some important shortcomings and also mistakes in considering and calculating very important parameters (water depth, velocity, discharge data, etc.). These kinds of problems must be taken away by strictly controlling EIARs; in Turkey, this mission has been officiated by experts, mostly via judicial processes. It can be seen in Table 2 that, for roughly half of the SHPs which have been studied in this study, EIAR is accepted; for the other half, EIA is rejected, i.e., is recommended to be amended.

4.4. Cumulative environmental impact assessment reports

As stated before, the cumulative impacts of various SHPs in a basin or within close locations must be considered. In Turkey, however, this issue has been ignored so far. It is of vital importance for the mitigation of environmental impacts of SHPs to take into consideration and to prepare EIARs by considering both cumulative impacts and bearing capacities of basins. An individual SHP should not be able to get a "good practice" certificate if it contributes to the elimination of the river ecosystem due to too many plants on one river, no matter how perfect its operations might be. Cumulative impacts of various projects and bearing capacity of a basin can only be determined and their negative effects can be minimized only by employing Integrated River Basin Management (IRBM) Plans.

4.5. IRBM approach

River basins are dynamic over space and time, and any single management intervention has implications for the system. Therefore, the management of river basins must include maintaining ecosystem functioning as a paramount goal. This ecosystem approach is a central tenet of the convention of biological diversity. IRBM rests on the principle that naturally functioning river basin ecosystems, including accompanying wetland and groundwater systems, are the source of fresh water. IRBM is the process of coordinating conservation, management, and development of water, land, and related resources across sectors within a given river basin, to maximize the economic and social benefits derived from water resources equitably while preserving and, where necessary, restoring freshwater ecosystems.

Integrated watershed management is an effective means for the conservation and development of land and water resources. As an interdisciplinary approach, it integrates the socio-cultural and economic as well as the biophysical and technological aspects of development. An over-riding concern of integrated watershed development is the improvement of the livelihoods of local communities on a sustainable basis. This requires balancing their economic needs and expectations with environmental concerns to avert degradation of the natural resource base, soil, and water components [26]. Comprehensive management should consider all uses of a water system and other activities that affect water flow and quality and information about the watershed's full hydrological regime.

Watershed planning process that should be developed for the watershed in which HEPPs are planned should have the following steps: Definition of objectives, developing of design criteria, usage or developing numerical pollution criteria, assessment of water body, developing alternatives, determining the implementation plan and performing post-implementation monitoring [27].

The main problem related to water management in Turkey is the lack of Integrated River Basin Management strategies. For example, in a small watershed in the Black Sea Region, there might be 10 to 20 river type HEPPs planned to be built, with no concern to predict or measure the total effect of those HEPPs on the environment. Aside from not having integrated river basin management plans, there are also no real regional or national plans for hydroelectric power production. All the sites that can potentially produce hydropower are identified and declared on the internet site of the DSİ. This identification is based on the technical feasibility of the projects and does not assess economic or environmental feasibility. Individual entrepreneurs pick a site they want to invest in and apply to the Energy Market Regulatory Authority (EPDK, in Turkish) for a license to build HEPPs. The applicant can then either build the HEPP or sell the license to other investors. By 2011, 4000 applications have been made to build HEPPs. Approximately 1000 of these have been built. Out of the 3000 potential projects, some will never be built because they would not be economically profitable. Some have been built only to realize later that original water flow estimates do not correspond to reality. Others are coming across tremendous opposition from local people and environmentalists for ruining the livelihoods of people and nature. Some had to stop construction due to court order because of the latter reasons. In short, no planning causes many victims; the environment loses its integrity, the local people lose their healthy way of life, the project owners lose the already invested money. In short, HEPP licenses are given individually and do not form part of a plan that considers economic, social, environmental, or even energetic concerns. The license is given if it is technically feasible to build a HEPP [28].

4.6. Key criteria and checklist on the eligibility criteria for SHPs

In the literature, various studies are given about the selection of SHPs, related both to key criteria and checklist on the eligibility criteria [24, 29, 30]. Here, a summary of them is presented. The most important key criteria are:

- The study area should be large enough to allow the assessment of VECs that may be affected by the action being assessed.
- Other actions that have occurred, already exist, or may yet occur that may also affect the same VECs should be identified. Future actions that are approved within the study area should be considered if they may affect those VECs and there is enough information about them to assess their impacts.
- The incremental additive effects of the proposed action and the total impacts of the proposed action and other actions on the VECs should be assessed.
- These impacts should be analyzed by quantitative techniques, if available, based on the best available data.
- Measures for mitigation, monitoring, and impact management should be recommended.

Depending on these key criteria, the following checklist must be realized and strictly controlled:

- Regulatory Compliance: SHP should comply with the requirements of the national environment, health, and safety law and should consider the cumulative impacts on the water basin resulting from existing developments.
- Water Discharge and Quality: The plant must maintain a minimum flow in the river that is adequate for the existing fish population, wildlife, and water quality and should not contribute to the deterioration of water quality either upstream or downstream sides.

• Fish Passage and Protection**:** The plant should have minimal impact on local fish populations, should provide effective fish passage for local and migrating fish species.
• Watershed Protection: SHP should not negatively impact environmental conditions in the watershed.
• Threatened and Endangered Species Protection: The facility must not negatively impact any threatened or endangered species.
• Community Issues: SHP should not reduce local community use of either the river or the surrounding lands.

5. CONCLUSION

In this study, some solution proposals to the environmental impacts of small hydropower plants (SHPs) in Turkey are analyzed. The main problems are categorized as construction and operation stages of SHPs, as well as about environmental impact assessment reports (EIARs) and cumulative impacts of various projects. Environmental impacts that arise during construction are short-termed problems and can be mitigated by proper construction techniques, such as usage of trained personal, appropriate machinery, and modern construction techniques. However, operational problems are long-termed, and coping up with them is a difficult challenge. The outstanding operational problem has been identified as both determination and controlling of environmental discharge (minimum flow), which is monitored to be the principal issue to give rise to public backlash. It is obvious that more studies should be carried out for proper calculation of this value and its continuous control is another great challenge, because of insufficient control crew and equipment. It is appropriate to develop some solutions regarding the subsequent determination and ensuring control (continuous control from a remote center by a unit with the system to be installed, etc.). Other operational problems, including fish and wildlife passages and destruction of sediment regime, can be easily solved by proper planning and design. Problems related to high voltage power lines should be dealt with in separate EIA reports.

There are pivotal shortcomings of EIARs. It has been noticed that the cumulative impacts of various facilities have not been considered almost for all of the SHPs in Turkey. As a result of this insufficiency, most of the hydrological basins have been overburdened by SHPs, beyond their bearing capacities, which has given rise to significant environmental degradation. The solution to this problem can only be achieved by preparing and applying scientific cumulative environmental impact assessment studies and by employing IRBM plans.

Some important key criteria and checklist on the eligibility criteria for determination, management, and mitigation of environmental impacts of SHPs in Turkey are also included at the end of the paper.

SHPs are not mandatory to build. When necessary, it should be ensured that it is actively supervised and implemented without compromising the issues mentioned in the article.

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