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경인 아라뱃길의 물환경 개선을 위한 오염원인 평가항목 및 지표 개발

Developing Evaluation Index and Item for Water Environment Improvement of Gyeongin ARA Waterway

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요약

본 연구에서는 델파이 기법과 AHP분석을 이용하여 경인 아라뱃길의 수질에 영향을 미치는 다양한 인자를 설정하고 하천의 수질을 체계적이고 객관적으로 평가할 수 있는 평가 항목 및 지표를 개발하였다. 분석 결과, 최상위 평가항목에서의 중요도는 물리·환경적 요인 28%, 관리적 요인 26%, 자연·고정적 요인 26%, 사회·문화적 요인이 20% 순으로 나타났다. 3계층 평가항목인 물리·환경적 요인의 내적 요인에서는 자정능력의 손실, 외적 요인에서는 귤현보 및 교량에 의한 오니토 퇴적이 중요도가 가장 높은 것으로 나타났으며, 관리적 요인의 시설요인에서는 축산 및 폐수처리시설의 영향, 정책/제도적 요인에서는 규제권역상의 문제로 나타났다. 또한 자연·고정적 요인의 수생태/점오염원에서는 굴포천의 오염수, 생활환경/비점오염원은 기타하천의 유입수로 나타났으며, 사회·문화적 요인에서 경제적 요인에서는 화물 및 여객운항, 외적 요인에서는 하수처리시설 부족에 따른 영향이 중요도가 가장 높은 것으로 나타났다. 이러한 결과들은 향후 경인 아라뱃길의 수질개선 사업의 우선순위를 산정할 수 있는 논리적 근거와 객관성을 마련하기 위하여 각각의 평가지표들을 측정할 수 있는 구체적인 방법론과 기법에 대한 연구가 지속되어야 할 것이다.

■ 중심어 : | 경인 아라뱃길 | 델파이기법 | 평가지표 | AHP |

Abstract

This research has developed the criteria and index for systematically and objectively assessing the quality of river water by fixing the various factors that affect Gyeongin ARA waterway's water quality through analysis with the Delphi Technique and analytic hierarchy program (AHP) Method. Based on the results, the highest criteria are, in order of importance, physical and environmental factors 28%, administrative factors 26%, natural·fixed factors 26% and finally, cultural and social factors 20%. The three dimensions of the criteria show that for the internal physical and environmental factors, the most important are the loss of self-purification capacity, and the external factors are Gulpocheon and the sludge deposit due to Gyulhweon-weir the bridge. The facility factor in management was affected by the coagulation and waste water disposal facilities. The problem for the policy and institutional factors was seen in the regulatory area. The aquatic ecology/ point pollution source for the natural·fixed factors show that it is due to the polluted water of Gulpo-cheon and the living environment/ non-point pollution source is shown through the inflow water from other rivers. Cultural and social factors show that the economical causes were due to the cargo and passenger flight operations and the external factors of having a lack of sewage treatment equipment have an importance effect. In order to estimate the order of priority through logical evidence and objectivity, future research must be continued on the evaluation indexes to measure the specific methodology and technique needed to improve the Gyeongin ARA Waterway.

■ keyword : | Delphi | Evaluation Index | Gyeongin ARA Waterway | Agriculture Water | AHP |

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Ⅰ. Introduction

The Gyeongin ARA waterway is the first canal built in 2011 in the Korea, roughly 18.7km waterway connecting the lower reaches of the Han River with the West Sea. Seawater and fresh water flows in to the ARA waterway through the lock gate constructed in the West Sea and the Han River, the difference of salinity causes stratification and a brackish water zone. However, domestic water quality criteria for the brackish water zone is not set up, the experience of operation & management of the canal is not enough, the uncertainty always exists in the waterway[1]. Furthermore, the pollution sources from the landfill near the Gyeongin ARA waterway has a harmful effect on the waterway and Gulpocheon as well, which flows into the ARA waterway via the city and the industrial complex[2]. KWRC(2013)[2] analysed the change of water quality of the waterway from 2012 to 2013, and found out that the various external factors such as water flow time, leachate of the landfill, sediment, etc. adversely affected the targeted water quality. In the light of salinity and water temperature of the ARA waterway, Yin and Seo(2013)[3] analysed the spatio-temporal water use and the feature of water quality according to operation of the lock gate by utilizing 3 dimensional numerical model, as a result of the analysis, it was revealed that the water quality near the lock gate in the side of the West Sea, where sea water flows in, is mostly satisfactory, by contrast, the nearer is water to the lock gate adjacent to the Han River, the more water quality worsens. Additionally, Inside of the Jooun waterway in spring and fall, it was confirmed that empty oxygen layer where DO drops below 2 mg/L created.

As the ARA waterway is the first canal located at the brackish water zone, the establishment of criteria for water quality control is needed in various point of view, but the detailed procedure and way for the improvement of the waterway's water quality is not practically prepared yet. Thus, accurate comprehension of the cause is needed in order to effectively achieve the control of pollution sources and the improvement of water quality and the concentration and selection of limited financial resources is required through suggesting an alternative. In addition, above all, systematic and precise assessment should be made for the purpose of controling water-purity of the ARA waterway, but currently systematic combination between assessment items reflecting the water quality of the waterway is not made yet. Therefore, the invention of systematic and precise evaluation items and an index is required to effectively achieve the control of pollution sources and the improvement of water quality and to maintain and manage the water quality of the stream. The study on selection of an alternative and invention of an evaluation index with a view to coping with and assessing the situation comprehensively in terms of technology, industrial management and planning has been mainly conducted in humanities and social sciences such as economics, business management, national defense, and politics by using multiple criteria decision making model, rarely carried out in the field of water resource planning and management. Choi et al.(2016)[4] developed evaluation indicators of dam rehabilitation considering climate change in order to prepare for safety of aging dam facilities in accordance with changes in rainfall intensity by using AHP analysis. Lee and Shim(2002)[5] used ahp analysis to prioritize water allocation in drought. The results of the analysis it has been concluded that the water allocation during drought should be accomlished in order of domestic, irrigation, industrial, and river maintenance water. Kang and Lee(2006)[6] surveyed 127 experts and used ahp analysis to analyze the importance of WRSI componen. the result of survey represented that efficiency and equity of water use and water quality for river restoration are mahor issues in enhancing the water resources sustainability. Yang and Kim(2013)[7] used the Delphi method to develop a vulnerability index for drought based on Nakdong watershed. Twelve indicators were selected based on three groups, ie hydrological, meteorological, and humanistic groups. Studies related to river water quality, Yeo(2011)[8] has developed the method for choosing alternative of water resources project and deciding investment priority by making use of Analytic Hierarchy Program, AHP. Park(2012)[9] has invented the assessment items for the improvement of water quality by using AHP with the intention of deciding the priority to restore the polluted stream and preparing for the solution to pollution sources. However, As these study selected indexes for the water quality assessment only based on theoretical characteristic, the selected indexes are not satisfactory in terms of field application. To compensate the defect, it is necessary to more subdivide the decision making process required to improve the water quality of the stream and to use a logical and objective methodology.

All the pollution sources should be controlled and purified, but more focus on controlling the most serious potential pollution sources in the region can contribute to prevention of water pollution through efficient allocation of resource and time. Thus the aim of the study is to select a variety of factors influencing the water quality of ARA waterway and to develop the assessment items and the index to be able to evaluate systematically and objectively the water environment of a stream. The assessment items are selected by the brainstorming of the related experts, the Delphi technique and analytic hierarchy program (AHP) method are used for the selection of the factors and the development of the index.

II. Research Methodology

In the research, Both Delphi technique and AHP analysis are for experts. The difference between two methods is that Delphi analysis is the method to ask how much agrees on one factor, AHP analysis is the method to ask which factor is more important one among more than two factors. Ultimately, Delphi analysis is for the assessment of the cause of water pollution, AHP analysis is for the selection of the factors that should be controlled more intensively for the ARA waterway. We make the priority model of overall evaluation items by using compound weight for an individual index in hierarchical assessment items of Delphi technique and AHP technique, and intend to provide the basic data for decision making process needed to improve the water quality of the Gyeongin ARA waterway hereafter. the procedure and method of the study are shown in [Fig. 1].

The assessment items are selected through their consultation by 40 experts in various field of civil engineering, environment, policy, and administration in order to reach a final conclusion for the improvement of water quality of the ARA waterway[Table 1]. For reflecting unbiased opinion, We divide the experts into two groups, namely technology experts and economics experts, pick the remaining score except the highest and the lowest score in each group, and calculate the total score. In the event that the respondents of the survey related to Delphi technique and AHP have little knowledge and understanding of the current state of ARA waterway, objective outcome of survey can not be obtained, thus researchers selected the survey participants after careful consideration, and made a prior explanation for the survey in order to meet Inconsistency Rate required in decision- making. Referentially, AHP is not a probability-based parametric statistical analysis methodology but a non-parametric methodology to calculate the weight. Thus, though the number of the sample is not important, at least 30 persons as a survey sample can make normal distribution. Generally, more than 30 samples is the minimum number of samples to be able to make normal distribution on the basis of central limit theorem. The study picks 40 persons as a sample. The survey tool consists of two topics, Delphi technique is designed to evaluate the items on main cause of, serious effect on, adverse effect on creation of water environment of ARA waterway on Likert-type scale of 5 points, meanwhile AHP technique is designed for the comparison method on the scale of 9 points.

1. Delphi Technique

Delphi method is developed in 1950s by US's Rand Corporation, is used to solve the urgent national defense in Cold War era after removing a limitations resulting from face-to-face discussion. The method can be used variously by utilizing experts in diverse fields, and can be also used as a mediation tool to assess the conflictual relationship of interested parties and to collect public opinion as well as to forecast the future owing to its easiness and simplicity in conducting a study. The parties concerned form a committee, discuss, and collect the opinions in order to solve the problems requiring a mutual consent of the interested parties[10]. Delphi method is panel-type survey method that can prevent possible negative

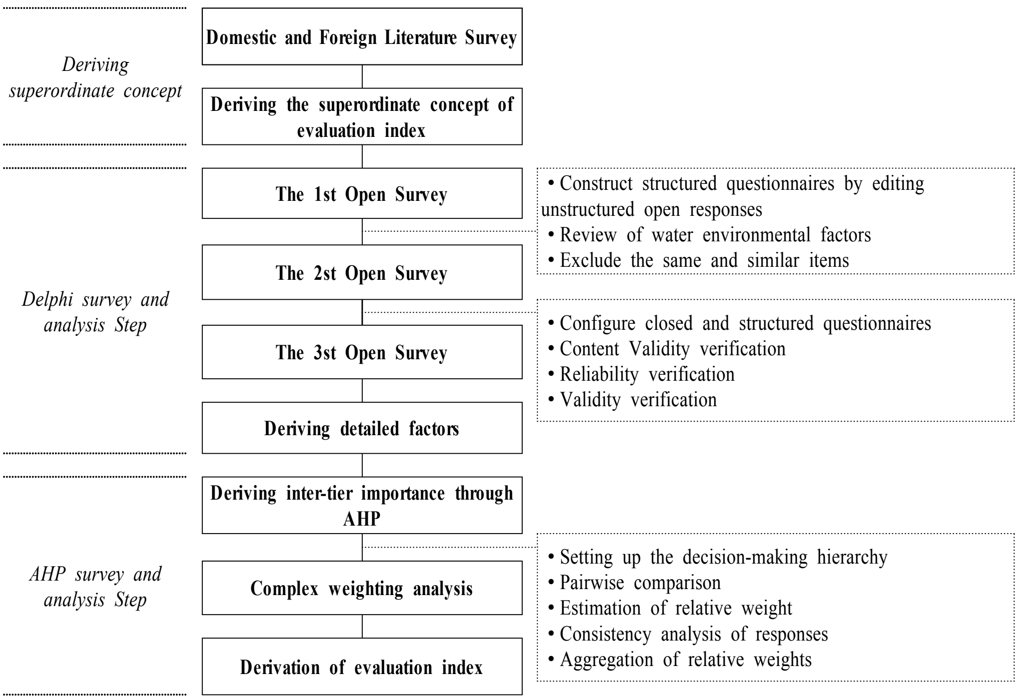

Fig. 1. Research procedure and method

effects in debate of the committee. The systematized communication of the debate participants enables the complicated problems to be effectively coped with. The systematization of communication make the collection of the opinions possible through ① repeated procedure and controlled feedback ② anonymity of respondents ③ the procedure of statistical group response[9][11][12].

Delphi technique offers opportunity for individual participants to revise their decision and make their judgement more perfect based on the outcome of the previous survey during the series of the survey. At the first stage of the survey, the questionnaire mainly contains the open-ended questions or the questions to let the respondents freely express their views. In the research, the first stage focuses on literature study, the main researchers chose the questions for the survey by means of Brainstorming.

From the second stage, in the case of a disagreement of the experts' opinion and the questions needed in additional discussion on the foundation of the analysed results, both the median value of total respondents and the value gained by each expert in the second stage are presented again to the experts. Each expert has a chance to change his/her opinion with comparing his/her opinion with other experts' opinions. The individual respondent should describe the reason regardless of the change of one's opinion. [Table 2] shows the structure of the survey tool to confirm internal consistency of respondents about the pollution sources in each round. The reliability coefficient was calculated by the repeated measurement, to draw a degree of convergence and a degree of consent, we examined again the degree of consent to the opinion with showing other experts the reason not to agree to the opinion at every stage. At last, we can get the opinion in accord through the repeated stage. Delphi technique presents the degree of the accord in the respondents' opinion by dint of the mathematical formulas, which are mostly reliability analysis(Cronbach's α), validity test, content validity

Table 1. Materials and information of Survey

division	Content
Survey participants	Civil Eng. 20, Environmental Eng. 15, Policy and Public administration 5 (Experience more than 5 years)
Number of people(academic background)	40 people (Bachelor 9, Master 20, Doctor 11)
Fields of work	professor and researcher 14, technical and specialized 17, public servant 9
Recovery ratio	100%
Contents of question	Importance and priority analysis for the evaluation items for Water Environment of Gyeongin ARA Waterway
Period	2015.1.~2015.4.(Total 4 months)

Table 2. Contents of the Delphi survey for investigation on the reasons of water pollution in Gyeongin ARA waterway

Clarification	Contents	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Landfill leachate of Seoul metropolitan areas	The main reason of water pollution in Gyeongin ARA water way was the landfill leachate from Seoul metropolitan areas.					
	The moderate reason of water pollution in Gyeongin ARA water way was the landfill leachate of Seoul metropolitan areas.					
	The landfill leachate of Seoul metropolitan areas was influenced the water pollution in Gyeongin ARA water way.					

ratio, the Convergence level and the Agreement level.

1.1 Reliablity

The reliability rate in Delphi analysis can be measured using generalizability coefficient, which equals to Cronbach's α coefficient[11]. The reliability rate coefficient means internal consistency of a respondent. so to speak, the coefficient represents how much the response pattern of a respondent is consistent. Cronbach's α can assess the reliability rate according to each area consisting of the measurement tool, and ranges from 0 to 1. By and large, the higher the value is the higher the reliability rate is, the minimum allowance of the reliability rate is more than 0.6, namely more thn 0.6 is reliable, less than 0.6 is insignificant. If any item is below 0.6, it may be judged that the item damages the total reliability[13][14].

1.2 Validity

Content Validity and Validity are used to verify the validity of Delphi technique. Content Validity is analysed based on Content Validity Ratio, CVR suggested by Lawshe(1975)[15]. CVR suggests a minimum value according to the number of panel, CVR over the minimum value is estimated to mean to be significant in Content Validity. The way to calculate CVR is Eq. (1) shown below.

$$CVR = (n - N/2)/(N/2) \qquad (1)$$

where, n is the number of response saying "important" and it means frequency of high value in a quartile. The minimum value of CVR depending on the number of the respondents is shown in [Table 3].

Validity can be suggested by analysing the level of convergence of opinion and a level of consent[11][16]. Convergence level has a value of 0 when all opinions are converged on one point and its value becomes large if the deviation of opinion is large. The agreement level has a value of 1 when Q_1 and Q_3 are in agreement and complete agreement, and the numerical value when the deviation of opinion is large decreases. In other words, the closer the Convergence level is to 0, the closer the Agreement level is to 1, the more meaningful the question is. The Convergence level and Agreement level are calculated as Eq. (2) and Eq. (3) respectively.

$$\text{Convergence level} = (Q_3 - Q_1)/2 \qquad (2)$$

$$\text{Agreement level} = 1 - [(Q_3 - Q_1)/Mdn] \qquad (3)$$

where, Mdn=median value, Q_1 and Q_3 mean 25% and 75% of the cumulative value of the total number of cases as the first quadrant position and three quartile coefficient, respectively.

2. AHP Technique

AHP(Analytic hierarchy process) is a multiple criteria decision method, which means that if the decision is made by multiple assessment criteria, the assessment criteria is stratified, the weight is set according to the hierarchy. This is invented by Saaty(1990)[17], and is systematic process to interpret efficiently complicated decision-making problems. AHP comprehends the level of the significance

Table 3. The lowest value of contents validity ratio according to the number of respondents[15]

Number of respondents	10	11	12	13	14	15	16	20	25	30	35	40
The lowest values of CVR	0.62	0.59	0.56	0.54	0.51	0.49	0.48	0.42	0.37	0.33	0.31	0.29

p=0.05

between target values in terms of the hierarchy, and based on it, measures the level of importance of each alternative. The AHP technique is fit for solving the decision-making problems embracing multiple aims, assessment criteria, and decision makers by means of stratification. AHP classifies extremely complicated non-structural situation into sub-factors, assigns the weight to each sub-factors in terms of the relative importance according to subjective judgement, and make a judgement comprehensively in order to obtain the desirable result representing the high priority[17].

In regard to the assessment by AHP, Saaty and Kearns(1985)[18] thought highly of AHP which is successfully applied to the various fields such as energy assignment plan, traffic system planning, future planning in companies, future scenario design, candidacy and election process, outlook for oil price, etc. Saaty and Vargas(1982)[19] praised AHP for its effectiveness in making a decision or a plan.

Ⅲ. The Outcome of the Analysis

1. The Outcome of Delphi Analysis

In the first and second stage of Delphi analysis process, we asked a series of intensive question to the experts over the fundamentally important problems influencing the water environment of ARA waterway, assessed or revised the expert's personal views after gathering and summarizing what the respondents answer, and so sought a solution to the water environment of the waterway with casting open-ended questions, confirmed and ranked the variety of cause factors. The outcome of the final third stage is shown in [Fig. 2]. In the third stage, all the experts reached the unified opinion, the reliability analysis and the validity analysis were carried out.

1.1 Reliability Analysis

When same concept is measured repeatedly by using a independent method, the reliability means the

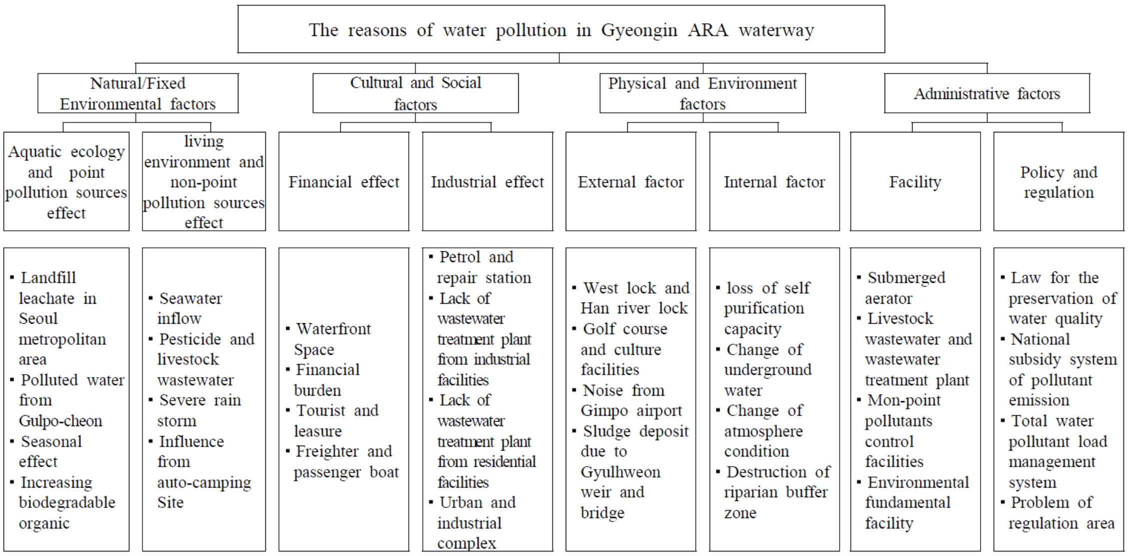

Fig. 2. The main factors and detailed sub criteria related to the water pollution in Gyeongin ARA waterway based on the Delphi Technique

variance of the measured value coming from the results. The study conducted the reliability analysis by utilizing Cronbach's α for the purpose of verifying the reliability.

[Table 4] indicates the outcome of the reliability analysis. The result of the reliability analysis is mostly more than 0.7, above the minimum allowance, the change of underground water records 0.929, the highest, in the category of physical/environmental factor. Though agricultural pesticides and livestock wastewater stands at 0.715 the lowest, its Cronbach's α scores over 0.6 in all items of 3 tiers, which is valid. Thus, the response pattern of 40 participants secures the internal consistency, it is judged that commonality exists in all the questions. This can be construed as the fact that 40 experts share entirely the critical mind and the judgement of a standard of value such as the assessment criteria in the selection of the factors in the process of Delphi analysis.

1.2 Validity Analysis

The less important pollution sources are eliminated in the first and second stage. Ultimately, we carry out

Table 4. Result of reliability analysis using Delphi Technique

Classification of factors			Cronbach's α
First class	Second class	Third class	
Natural/Fixed Environmental factors	Aquatic ecology and point pollution sources effect	Landfill leachate in Seoul metropolitan area	0.802
		Polluted water from Gulpo-cheon	0.818
		Seasonal effect	0.863
		Increasing biodegradable organic	0.901
	Living environment and non-point pollution sources effect	Seawater inflow	0.780
		Pesticide and livestock wastewater	0.715
		Severe rain storm	0.844
		Influence from auto-camping Site	0.828
Cultural and social factors	Financial effect	Waterfront Space	0.822
		Financial burden	0.907
		Tourist and leasure	0.846
		Freighter and passenger boat	0.871
	Industrial effect	Petrol and repair station	0.789
		Lack of wastewater treatment plant from industrial facilities	0.826
		Lack of wastewater treatment plant from residential facilities	0.775
		Urban and industrial complex	0.843
Physical and environment factors	External factor	West lock and Han river lock	0.878
		Golf course and culture facilities	0.801
		Noise from Gimpo airport	0.869
		Sludge deposit due to Gyulhweon weir and bridge	0.833
	Internal factor	Loss of self purification capacity	0.874
		Change of underground water	0.929
		Change of atmosphere condition	0.822
		Destruction of riparian buffer zone	0.813
Administrative factors	Facility	Submerged aerator	0.868
		Livestock wastewater and wastewater treatment plant	0.783
		Mon-point pollutants control facilities	0.844
		Environmental fundamental facility	0.739
	Policy and regulation	Law for the preservation of water quality	0.889
		National subsidy system of pollutant emission	0.729
		Total water pollutant load management system	0.805
		Problem of regulation area	0.742
Average			0.827

the final third Delphi analysis focusing on the major factors that more than the half of the experts select the pollution sources as. As indicated in the outcome of validity analysis, in all the items, CVR=0.34 to 0.9, The range of Convergence level is 0.165 to 0.525, and the range of Agreement level is 0.443 to 0.915, all are valid. When it comes to median value, sludge deposit by Gyulhyeon weir and the bridge stands at 5.0, the most important pollution sources. As for CVR, as shown in [Table 3], the minimum value according to the respondents indicates more than 0.29 in all items, it turns out that the major pollution sources picked in

Table 5. The result of content validity based on the Delphi Technique

Factor			SD	Median (Mdn)	25% (Q1)	75% (Q3)	CVR	Convergence level	Agreement level
Natural/Fixed Environmental factors	Aquatic ecology and point pollution sources effect	Landfill leachate in Seoul metropolitan area	0.65	4.00	3.66	4.33	0.34	0.335	0.833
		Polluted water from Gulpo-cheon	0.47	4.66	4.33	5.00	0.75	0.335	0.856
		Seasonal effect	0.82	4.00	2.58	4.00	0.34	0.510	0.645
		Increasing biodegradable organic	0.71	4.00	3.16	4.00	0.44	0.420	0.790
	Living environment and non-point pollution sources effect	Seawater inflow	0.35	3.33	3.00	3.33	0.50	0.165	0.901
		Pesticide and livestock wastewater	1.01	4.33	3.33	5.00	0.35	0.435	0.614
		Severe rain storm	0.69	2.66	2.33	3.33	0.85	0.500	0.624
		Influence from auto-camping site	0.78	3.00	2.33	3.33	0.65	0.500	0.667
Cultural and social factors	Financial effect	Water front Space	0.87	3.00	2.33	4.00	0.49	0.435	0.443
		Financial burden	0.76	3.00	2.33	3.58	0.75	0.525	0.583
		Tourist and leasure	0.82	3.50	3.00	4.00	0.49	0.500	0.714
		Freighter and passenger boat	0.70	3.66	3.00	3.91	0.50	0.455	0.751
	Industrial effect	Petrol and repair station	0.80	4.00	3.00	4.00	0.49	0.500	0.750
		Lack of wastewater treatment plant from industrial facilities	0.88	4.66	4.00	5.00	0.65	0.500	0.785
		Lack of wastewater treatment plant from residential facilities	0.80	4.66	4.00	5.00	0.60	0.500	0.785
		Urban and industrial complex	1.02	4.00	3.66	4.33	0.44	0.335	0.833
Physical and environment factors	External factor	West lock and Han and Han river lock	0.62	4.00	3.41	4.00	0.49	0.295	0.853
		Golf course and culture facilities	0.99	3.66	2.33	4.33	0.39	0.500	0.454
		Noise from Gimpo airport	0.80	3.00	2.33	3.00	0.50	0.335	0.777
		Sludge deposit due to Gyulhweon weir and bridge	0.37	5.00	4.33	5.00	0.50	0.335	0.866
	Internal factor	Loss of self purification capacity	0.52	4.33	3.75	4.33	0.50	0.290	0.866
		Change of underground water	0.66	3.00	2.33	3.33	0.90	0.500	0.667
		Change of atmosphere condition	0.45	3.00	2.66	3.33	0.50	0.335	0.777
		Destruction of riparian buffer zone	0.56	4.00	3.66	4.00	0.39	0.170	0.915
Administrative factors	Facility	Submerged aerator	0.96	3.00	2.33	4.00	0.44	0.435	0.443
		Livestock wastewater and wastewater treatment plant	0.80	4.00	3.75	5.00	0.50	0.425	0.688
		Mon-point pollutants control facilities	0.68	3.66	3.00	4.00	0.49	0.500	0.727
		Environmental fundamental facility	0.77	2.66	2.33	3.33	0.80	0.500	0.624
	Policy and regulation	Law for the preservation of water quality	0.92	2.00	2.00	3.00	0.90	0.500	0.500
		National subsidy system of pollutant emission	0.99	2.00	1.00	3.00	0.85	0.500	0.600
		Total water pollutant load management system	1.07	1.66	1.00	3.00	0.50	0.500	0.605
		Problem of regulation area	1.13	2.33	1.33	3.00	0.85	0.435	0.683
Average							0.57	0.422	0.707

the process of the Delphi analysis at the third stage has common pathway as the 40 experts point out together. In Convergence level and Agreement level, 0.615 to 0.5, 0.434 to 0.915 respectively, more than half of respondents recognized as the cause of pollution, It was found that there is no value exceeding 0.5 point

Table 8. The criteria and each index assessing the quality of river water in Gyeongin ARA waterway

Decision making factor		Detail factor	Relative importance	transformed score	A	B					Total (A*B)
					5 point scales (1 point standard)	5 Excellent	4 Very good	3 Good	2 Fair	1 Poor	
Natural/Fixed Environmental factors	Aquatic ecology and point pollution sources effect	Landfill leachate in Seoul metropolitan area	0.28	3.60	0.72						
		Polluted water from Gulpo-cheon	0.51	6.60	1.32						
		Seasonal effect	0.09	1.20	0.24						
		Increasing biodegradable organic	0.12	1.60	0.32						
	Living environment and non-point pollution sources effect	Seawater inflow	0.30	3.90	0.78						
		Pesticide and livestock wastewater	0.36	4.70	0.94						
		Severe rain storm	0.18	2.40	0.48						
		Influence from auto-camping Site	0.16	2.00	0.40						
Sub total				26	-						
Cultural and social factors	Financial effect	Water front Space	0.19	1.90	0.38						
		Financial burden	0.22	2.20	0.44						
		Tourist and leasure	0.27	2.60	0.52						
		Freighter and passenger boat	0.32	3.30	0.66						
	Industrial effect	Petrol and repair station	0.08	0.80	0.16						
		Lack of wastewater treatment plant from industrial facilities	0.33	3.30	0.66						
		Lack of wastewater treatment plant from residential facilities	0.46	4.60	0.92						
		Urban and industrial complex	0.13	1.30	0.26						
Sub total				20	-						
Physical and environment factors	External factor	West lock and Han river lock	0.18	2.50	0.50						
		Golf course and culture facilities	0.17	2.30	0.46						
		Noise from Gimpo airport	0.12	1.70	0.34						
		Sludge deposit due to Gyulhweon weir and bridge	0.53	7.50	1.50						
	Internal factor	loss of self purification capacity	0.36	5.10	1.02						
		Change of underground water	0.13	1.80	0.36						
		Change of atmosphere condition	0.33	4.60	0.92						
		Destruction of riparian buffer zone	0.18	2.50	0.50						
Sub total				28	-						
Administrative factors	Facility	Submerged aerator	0.28	3.70	0.74						
		Livestock wastewater and wastewater treatment plant	0.43	5.60	1.12						
		Mon-point pollutants control facilities	0.14	1.80	0.36						
		Environmental fundamental facility	0.15	1.90	0.38						
	Policy and regulation	Law for the preservation of water quality	0.23	3.00	0.60						
		National subsidy system of pollutant emission	0.30	3.90	0.78						
		Total water pollutant load management system	0.17	2.20	0.44						
		Problem of regulation area	0.30	3.90	0.78						
Sub total				26	-						
Total				100	-						

or less than 0.5 point respectively. Therefore, judged that expert opinion had converged.

2. AHP Analysis

AHP is the method to analyse by means of comparison in order to decide the relative importance. The research classifies pollution factors and carries out the relative importance analysis. As the result of AHP analysis at the first tier, the consistency ratio stands at 0.196, which means valid. the importance priority is 0.281 in the pysical/environmental factor, 0.258 in the administrative factor, 0.257 in the natural/fixed factor, 0.201 in the social/cultural factor in descending order[Table 6].

[Table 7] shows the priority order at three tier and the result of the importance. As the result, in the assessment items of three tiers, polluted water from Gulpo-cheon at aquatic ecology and point pollution sources in natural/fixed factors stands at 0.507, pesticide and livestock wastewater flowed in from other stream at living environment and non-point pollution sources indicates at 0.360, freighter and passenger boat at financial factor in social and cultural factors is 0.327, lack of wastewater treatment plant at external factor records at 0.457, the highest in importance. Loss of self purification capacity at internal factor in physical and environmental factors is 0.363, sludge deposit due to Gyulhweon weir and bridge at external factor stands at 0.533, the highest in importance, livestock wastewater and wastewater treatment plant at facility factor in administrative factors stands at 0.431, problem of regulation area at policy and regulation factor indicates at 302, the highest in importance.

3. Development of Assessment Index

The researchers invented an assessment index and a score sheet for ARA waterway through analysing the weight and the transformed score based on the relative priority order between assessment items on the basis of the outcome of Delphi technique and AHP analysis[Table 8]. As shown in [Table 8], the assessment items such as ‘sludge deposit due to Gyulhweon weir and bridge′, ‘polluted water from Gulpo-cheon’, ‘influent water from other stream’, ‘loss of self purification capacity’, ‘problem of regulation area’, ‘livestock wastewater and wastewater treatment plant’, ‘Lack of wastewater treatment plant’ are put in the high rank of the priority order. In particular, sludge deposit, polluted water, influent water from other stream means an influx of the external pollution sources, it is judged that nutrient salts containing phosphorus and introgen has an effect on the water quality of the Gyeongin ARA waterway, therefore, the excessive amount of nutrient salts contained in the influent external pollution sources is required to be controlled. Given the relatively high weight of ‘Freighter and passenger boat’, the need of investigation and analysis over how much the passing of vessels has an effect on the change of water quality emerges, the importance of the administrative factor such as policy and regulation factors is revealed.

Ⅳ. Conclusion

The study selected the various factor affecting the water environment of the Gyeongin ARA waterway, and used Delphi technique and AHP in order to develop the assessment items and the index for systematic and objective evaluation in terms of the control of water quality.

We selected the 4 categories for the assesment, namely physical·environmental, administrative, natural·fixed, and social·cultural factor with a view to comprehensively evaluating the current state of the

Gyeongin ARA waterway, and selected 2 items per category at the second tier, 4 items per the items of the second tier at the third tier as the sub-factors for the evaluation. In the 4 categories, the physical·environmental factor is 28% in terms of importance, the administrative factor 26%, the natural·fixed factor 26% and the social·cultural factor 20% in descending order.

As for three tiers in the evaluation items, loss of self purification capacity at the internal factor in the physical·environmental factors, sludge deposit due to Gyulhweon weir and bridge at the external factor is the highest in terms of importance, livestock wastewater and wastewater treatment plant at the facility factor in the administrative factors, problem of regulation area at the policy and regulation factor, polluted water from Gulpo-cheon at the aquatic ecology and point pollution sources factor in the natural/fixed environmental factors, influent water from other stream at the living environment and non-point pollution sources factor, freighter and passenger boat at the financial factor in the cultural and social factors, lack of wastewater treatment plant at the external factor is the highest in terms of importance.

The purpose of the study is to examine that what kind of methodology for the survey and the analysis should be used in order to improve the water environment of streams including the Gyeongin ARA waterway, and to recognize the necessity for a systematic and scientific approach, and to suggest that in empirical side, the measure for concrete assessment method and technique should be considered. Additionally, given that the pursuit of a solution to an assessment method and technique should be required, the study was attempted in the hope of plenty of further studies following the study. From now on, the precautionary policy for the control of water quality should be set up with a view to subdivide the decision-making process for the improvement of water quality of the Gyeongin ARA waterway and then prepare for a logical basis and an objectivity to evaluate the priority order of water quality improvement project. with regard to applicability in real sites, the discussion should be carried on steadily on detailed methodology and technique to be able to measure respective assessment item.

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